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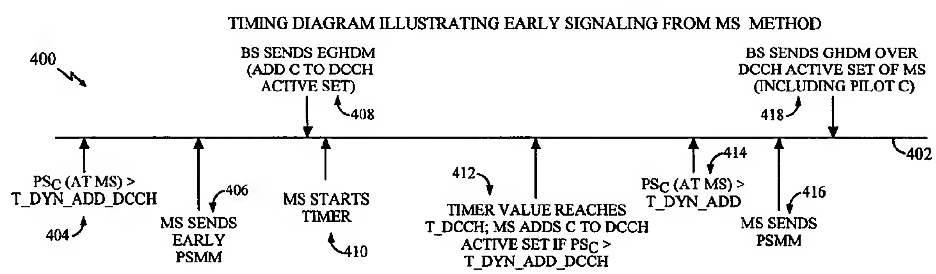

(57) Abstract: A method and apparatus for high data rate communication in a cellular/PCS communication system is provided. Specifically, the main embodiment provides for early assignment of code channel for signaling channels (F-DCCH) in soft handoff. Thus, rather than simultaneously assigning a code channel for signaling data and another for traffic data for a particular Mobile Station (MS)(116, 118) in soft handoff, the code channel is assigned earlier for signaling data. Some of the unnecessary Base Station (BS)(112, 114) procedures with respect to the signaling data may be eliminated. An additional embodiment includes the concept of early signaling from the MS (116, 118). The MS requests a code channel for signaling data, optionally followed by a request of a code channel for traffic data. This permits the MS (116, 118) to have the F-DCCH in soft handoff before having the F-DTCH (Forward Dedicated Traffic Channel) in soft handoff without requiring the BS (112, 114) to skip any of its procedures.

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METHOD AND APPARATUS FOR SOFT HANDOFF IN A CDMA COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to digital wireless communication systems. More particularly, the present invention relates to a novel and improved method and apparatus for early soft handoff in a code-division multiple access (CDMA) communication system.

II. Description of the Related Art

In the field of wireless communications, several technology-based standards exist for controlling communications between a mobile station, such as a cellular telephone, Personal Communication System (PCS) handset, or other remote subscriber communication device, and a wireless base station. These include both digital-based and analog-based standards. For example, among the digital-based cellular standards are the Telecommunications Industry Association/Electronic Industries Association (TIA/EIA) Interim Standard IS-95 series including IS-95A, IS-95B and IS-95C (also known as CDMA2000) entitled "Mobile Station - Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System." Similarly, among the digital-based PCS standards are the American National Standards Institute (ANSI) J-STD-008 series, entitled "Personal Station - Base Station Compatibility Requirements for 1.8 to 2.0 GHz Code Division Multiple Access (CDMA) Personal Communication Systems." Other non-CDMA based digital standards include the time-division multiple access (TDMA) based Global System for Mobile Communications (GSM), and the U.S. TDMA standard TIA/EIA IS-54 series.

The spread spectrum modulation technique of CDMA has significant advantages over other modulation techniques for multiple access communication systems. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Patent No. 4,901,307, issued February 13, 1990, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS", assigned to the assignee of the present invention, of which the disclosure thereof is incorporated by reference herein.

Space or path diversity is obtained by providing multiple signal paths through simultaneous links from a mobile user through two or more cell-sites. Furthermore, path diversity may be obtained by exploiting the multipath environment through spread spectrum processing by allowing a signal arriving with different propagation delays to be received and processed separately. Examples of path diversity are illustrated in U.S. Patent No. 5,101,501, issued March 31, 1992, entitled "SOFT HANDOFF IN A CDMA CELLULAR TELEPHONE SYSTEM", and U.S. Patent No. 5,109,390, issued April 28, 1992, entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR TELEPHONE SYSTEM", both assigned to the assignee of the present invention and incorporated by reference herein.

The deleterious effects of fading can be further controlled to a certain extent in a CDMA system by controlling transmitter power. A system for cell-site and mobile unit power control is disclosed in U.S. Patent No. 5,056,109, issued October 8, 1991, entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM", Serial No. 07/433,031, filed November 7, 1989, also assigned to the assignee of the present invention. The use of CDMA techniques in a multiple access communication system is further disclosed in U.S. Patent No. 5,103,459, issued April 7, 1992, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", assigned to the assignee of the present invention, of which the disclosure thereof is incorporated by reference herein.

The aforementioned patents all describe the use of a pilot signal used for acquisition in a CDMA wireless communication system. At various times when a wireless communication device such as a cellular or PCS telephone is energized, it undertakes an acquisition procedure which includes, among other things, searching for and acquiring the pilot channel signal from a base station in the wireless communication system. For example, demodulation and acquisition of a pilot channel in a CDMA system is described in more detail in copending U.S. Patent Application Serial No. 08/509,721, entitled "METHOD AND APPARATUS FOR PERFORMING SEARCH ACQUISITION IN A CDMA COMMUNICATION SYSTEM," assigned to the assignee of the present invention and incorporated herein by reference. When more than one pilot channel can be acquired by the wireless communication device, it selects the pilot channel with the strongest signal. Upon acquisition of the pilot channel, the wireless communication device is rendered capable of acquiring additional channels from the base station that are required for communication. The structure and function of these other channels is described in more detail in the above referenced U.S. Patent No. 5,103,459 and will not be discussed in detail herein.

The above standards and patents describe, among other things, the manner in which a mobile station is to execute a "handoff" between neighboring base stations as it travels between their respective geographic coverage areas. For example, in the CDMA-based standards IS-95 and J-STD-008, the base station sends a message to the mobile station listing many of the system parameters of its neighboring base stations, including such information as would assist the mobile station in executing an "autonomous" handoff between base stations. An autonomous handoff is one that is not initiated or directed by the base station, but rather is initiated by the mobile station itself.

An example of one such neighbor list message is the "Extended Neighbor List Message" of J-STD-008. When the base station sends an Extended Neighbor List Message to the mobile station, it uses the format of Table I.

TABLE I

Field	Length (bits)
MSG_TYPE ('00001110')	8
PILOT_PN	9
CONFIG_MSG_SEQ	6
PILOT_INC	4
Zero or more occurrences of the following record:	
NGHBR_CONFIG	3
NGHBR_PN	9
SEARCH_PRIORITY	2
FREQ_INCL	1
NGHBR_BAND	0 or 5
NGHBR_FREQ	0 or 11
RESERVED	0-7 (as needed)

The above table is taken from Section 3.7.2.3.2.14 of J-STD-008, and indicates the various fields transmitted in an exemplary Extended Neighbor List Message. Of particular concern to the present invention are the following fields:

NGHBR_PN - the base station sets this field to the pilot PN sequence offset for this neighbor, in units of 64 PN chips; and

NGHBR_FREQ - the base station sets this field to the CDMA channel number corresponding to the CDMA frequency assignment for the CDMA channel containing the paging channel that the mobile station is to search.

Thus, according to J-STD-008, the mobile station is given the frequency and PN offset of each neighboring base station. This gives the mobile station enough information to make a more focused search for neighbor pilots, rather than having to search all possible PN offsets on all possible CDMA frequency assignments. For example, the mobile station may keep a table of all the neighbors that were passed to it in the neighbor list message or extended neighbor list message. Such a table might resemble Table II below.

TABLE II

PN Offset (chips)	Frequency
12	f(1)
24	f(1)
48	f(1)
12	f(2)

With respect to "same-frequency neighbors," i.e. those that are on frequency f(1), the very nature of a CDMA modulation scheme allows a mobile station with a diversity receiver such as that described in the above-mentioned U.S. Patent No. 5,109,390 to search for other pilot signals on the same frequency assignment, but having different PN offsets, while simultaneously continuing to demodulate any channel that it is already monitoring. In other words, a CDMA mobile station is typically able to search for the pilot signals of other base stations on the same frequency assignment, without interrupting transmission or reception of data with its original base station.

Current Cellular/PCS systems are do not have the capability to handle large data transfers that occur in computing situations including internet environments. What is needed is a solution to the need to carry large amounts of data in addition to voice.

SUMMARY OF THE INVENTION

An embodiment of the invention provides a method and apparatus for high data rate communication in a cellular/PCS communication system. Specifically, the embodiment provides for early assignment of code channel for signaling channels (F-DCCH) in soft handoff. Thus, rather than simultaneously assigning a code channel for signaling data and another for traffic data for a particular Mobile Station (MS) in soft handoff, the code channel is assigned earlier for signaling data. Some of the unnecessary Base Station (BS) procedures with respect to the signaling data may be eliminated. An

embodiment includes the concept of early signaling from the MS to request a code channel for signaling data, optionally followed by signaling (at a later time) from the MS to request a code channel for traffic data. This permits the MS to have the F-DCCH in soft handoff before having the F-DTCH (Forward Dedicated Traffic Channel) in soft handoff without requiring the BS to skip any of its procedures.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a representative system in which an embodiment of the present invention resides.

Fig. 2 illustrates a functional block diagram of a Code Division Multiple Access system transceiver.

Fig. 3 illustrates a timeline representing the methodology of an embodiment of the present invention.

Fig. 4 illustrates a timeline representing the methodology of another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig. 1, system controller and switch 110, also referred to as a mobile telephone switching office (MTSO), typically includes interface and processing circuitry for providing system control to the cell-sites. Controller 110 also controls the routing of telephone calls from a public switched telephone network (PSTN) to an appropriate cell-site for transmission to an appropriate mobile or subscriber unit. Controller 110 also controls the routing of calls from the mobile or remote subscriber units, using at least one cell-site, to the PSTN. Controller 110 may connect or link calls between subscriber users using the appropriate base stations since the subscriber units do not typically communicate directly with one another.

Controller 110 may be coupled to the cell-sites by various means such as dedicated telephone lines, optical fiber links, or microwave communication links. In Fig. 1, two such exemplary cell-sites 112 and 114 are shown along with mobile units 116 and 118, where each mobile unit includes a cellular telephone. Exemplary cell-sites 112 and 114, as discussed herein and as illustrated in the drawings, are considered as providing service to an entire cell. However, it should be understood that a cell may be geographically divided into sectors with each sector providing service to a different coverage area. Accordingly, handoffs are generally required to be made between sectors within a cell, while diversity may also be achieved between sectors as is done between cells.

In Fig. 1, lines 120a-120b and 122a-122b, along with their respective arrowheads, correspond to signal transmission, which includes data transmission over various traffic channels, between cell-site 112 and mobile units 116 and 118, respectively. Similarly, lines 124a-124b and 126a-126b represent communication between cell-site 114 and mobile units 118 and 116, respectively. Cell-sites 112 and 114 nominally transmit using equal power.

The coverage of cell-site service areas or cells is designed or laid out in geographic shapes such that the mobile units will normally be closest to one cell-site, and within only one sector if cell is divided into sectors. When the mobile unit is idle, i.e. no calls in progress, the mobile unit constantly monitors pilot signal transmissions from each nearby cell-site, and, if applicable, from a single cell-site if the cell is sectorized. Mobile unit 116 can determine which cell it is in by comparing signal strength for pilot signals transmitted from cell-sites 112 and 114.

In the example illustrated in Fig. 1, mobile unit 116 may be considered closest to cell-site 112. When mobile unit 116 initiates a call, a control message is transmitted to the nearest cell-site, here cell-site 112. Cell-site 112, upon receiving the call request message, transfers the called number to system controller 110. System controller 110 then connects the call through the PSTN to the intended recipient.

Should a call be initiated within the PSTN, controller 110 transmits the call information to all of the cell-sites in the area. The cell-sites in return transmit a paging message within each respective coverage area that is intended for the called recipient mobile user. When the intended recipient mobile unit "hears" or receives the page message, it responds with a control message that is transmitted to the nearest cell-site. This control message signals the system controller that this particular cell-site is in communication with the paged mobile unit. Controller 110 then routes the call through this cell-site to the mobile unit. Should mobile unit 116 move out of the coverage area of the initial cell-site, 112, an attempt is made to continue the call by routing the call through another cell-site.

In the exemplary system of Fig. 1, orthogonal Walsh functions are assigned to user channels on the cell-to-subscriber link. In the case of voice channels, the digital symbol stream for each voice signal is multiplied by its assigned Walsh sequence. The Walsh coded symbol stream for each voice channel is then multiplied by the outer PN coded waveform. The resultant spread symbol streams are then added together to form a composite waveform. Another embodiment of the present invention includes assigning orthogonal Walsh functions on the subscriber-to-cell link.

The resulting composite waveform is then modulated onto a sinusoidal carrier, bandpass filtered, translated to the desired operating frequency, amplified and radiated by the antenna system. Alternate embodiments of the present invention may interchange

the order of some of the operations just described for forming the cell-site transmitted signal. For example, it may be preferred to multiply each voice channel by the outer PN coded waveform and perform the filter operation prior to summation of all the channel signals which are to be radiated by the antenna. It is well known in the art that the order of linear operations may be interchanged to obtain various implementation advantages and different designs.

The waveform design of the preferred embodiment for cellular service uses the pilot carrier approach for the cell-to-subscriber link, as is described in U.S. Pat. No. 4,901,307. All cells transmit a pilot carrier using the same 32,768 length sequence, but with different timing offsets to prevent mutual interference.

As is described in greater detail below, the symbol stream for a particular cellular user is combined in a first exclusive OR operation with the Walsh sequence assigned to that user. The Walsh function is typically clocked at a rate of 1.2288 MHz, 3.6864 MHz or 4.096 MHz while in an exemplary variable data rate system including voice, facsimile (FAX), and high/low-speed data channels the information symbol rate may vary from approximately 75 Hz to 76,800 Hz. The resulting coded waveform is combined in a second exclusive OR operation with a binary PN sequence also clocked at 1.2288 MHz. Another embodiment of the present invention includes a clock sequence in the range of 3 – 5 Mhz or above. Specifically, a preferred embodiment includes the rates of 3.6864 Mhz and 4.096 Mhz. An identical binary PN sequence is used to encode each subscriber channel within a particular sector of the coverage area of the cellular system. As a consequence of the orthogonality of the Walsh coding sequences, each sequence may be used to process user data on a single RF channel associated with such a sector without inducing interference among the users within the sector.

Prior to application of Walsh coding, the signals carried by each channel may also be convolutional or Turbo encoded, with repetition, and interleaved in order to provide error detection and correction functions which allow the system to operate at a much lower signal-to-noise and interference ratio. Techniques for convolutional or Turbo encoding, repetition, and interleaving are well known in the art. The resulting signals are then generally modulated onto an RF carrier and summed with the pilot and setup carriers, along with the other voice carriers. Summation may be accomplished at several different points in the processing such as at the IF frequency, or at the baseband frequency either before or after multiplication by the PN sequence associated with the channels within a particular cell.

Each voice/data carrier may also be multiplied by a value that sets its transmitted power relative to the power of the other voice carriers. This power control feature allows power to be allocated to those links that require higher power due to the intended recipient being in a relatively unfavorable location. Means are provided for the

subscribers to report their received signal-to-noise ratio to allow the power to be set at a level that provides for adequate performance without wasting power. The orthogonality property of the Walsh functions is not disturbed by using different power levels for the different voice carriers provided that time alignment is maintained.

A preferred embodiment of the present invention includes coherent demodulation and fast power control of both the forward and reverse links. Optionally, the preferred embodiment may be, but need not be, backwards compatible with IS-95 series of related standards.

Turning now to Fig. 2, a transceiver in an embodiment of the present invention is illustrated. The transceiver may be a mobile station or an essentially fixed external (base) station. Input data 204 typically includes a vocoded voice or data signal. The signal is then convolutionally encoded in encoder 206 where redundant information bits are added for forward error correction. The resultant data signal is then directed into interleaver 208 where the signal is then interleaved through time diversity to reduce the effect of fast fading on the signal at the eventual receiver. The interleaved signal is combined in mixer 212 with a user mask 210 at a frequency of interest decimated to a lower frequency, typically 19.2 kbps for identification purposes. In a preferred embodiment, the frequency of interest is selected from (although not restricted to) a range of frequencies between 1MHz and 5 MHz, but is preferably 1.2288 MHz, 3.6864 MHz or 4.096 MHz.

The signal output from mixer 212 is optionally combined in mux 216 with a power control signal 214 that is punctured into the signal before being sent to mixer 218. In mixer 218 the signal is combined with a signal from spreader 220 at a frequency of interest as above, which in the preferred embodiment of the invention is of the same frequency, though it need not be. Spreader 220 contains a Walsh code generator operating at the frequency of interest.

The resultant signal is sent to amplifier 222 whose power output level 226 is controlled by controller 228 by way of power control signal input 224. Controller 228 is shown as attached to both receiver and transmitter, however the forward and reverse links optionally may be symmetrical in some implementations of the preferred embodiments. Transceiver 200 is located at both a base station and a mobile station, but is programmed differently depending on the implementation.

Spreader 220 may be similar to that found in a forward or reverse link as described in IS-95. Specifically, the forward link and also reverse link may use orthogonal Walsh codes to separate the different user channels, or alternatively, different channels for the same user. An embodiment of the invention uses orthogonal Walsh codes to separate the different user channels instead of using the Walsh encoding

to reduce intersymbol interference. Additionally, the reverse (mobile-to-base station) link optionally utilizes coherent demodulation at the external base station.

Additionally, since both the reverse and forward links in an embodiment of the invention utilize coherent demodulation, transceiver 200 may be located within the mobile station and/or the external base station.

At the receiver 230, input signal 231 arrives at downconverter mixer 234 where it is combined with variable local oscillator 232. A multi stage downconversion apparatus and process are illustrated in a single stage for simplicity. The downconverted signal is passed to RAKE receiver 236 for coherent demodulation of various received multipath signals. The received signals are then passed to combiner 238 where the signals are added in phase before being passed to deinterleaver 240. The signal is then sent to decoder 242 and the final output signal 244 is passed from receiver 230. Controller 228 contains all the functionality required to control both receiver 230 and transmitter 202.

IS-95C Forward Link - Dedicated Control Channel Characteristics

A Forward Link Dedicated Control Channel (F-DCCH) in IS-95C facilitates transmission of the user-specific signaling messages from the Base Station (BS) to the Mobile Station (MS) while reducing potential disruption to the user traffic. User-specific signaling messages are necessary to maintain the radio link between the MS and the BS (e.g., handoff direction messages) and, in addition, for the management of Media Access Control (MAC) issues related to the user. Further, information exchanges from BS to MS on the F-DCCH are needed even when no communication is in progress.

Usually for voice services the frequency of signaling data may be low. Due to the low signaling activity, the TIA/EIA-95 standard permits the BS to multiplex this signaling data with the user traffic frames using the methods of dim-and-burst and blank-and-burst mechanisms. Clearly, these methods work well if the information data is not required to be transmitted in real time or if the service quality could tolerate some degradation. For real time services such as video and motion image data, this method suffers from degradation of service quality. Furthermore, if the signaling data occurs frequently as may be the case for a variety of services such as multimedia services, this problem becomes more severe. IS-95C supports a rather sophisticated MAC layer primarily for packet data and multimedia services. In this case, a large amount of signaling data in the form of MAC messages are expected to be transmitted between the BS and the MS.

A preferred embodiment of the invention provides the capability for the physical channel to signal data separate from the physical channel for traffic data when the MS

operates in certain predetermined modes. The physical channel which carries this signaling (or control) data is referred to as the F-DCCH (Forward Dedicated Control Channel). Two methods are considered. One is a common physical channel for signaling data is shared by multiple MS's. The other method is to assign a dedicated physical channel for signaling data for each MS. The former method makes more efficient use of the Walsh code resources. However, with the latter method, the delay incurred by the dedicated signaling data is smaller, especially when the volume of signaling data from the BS to the MS is large. In addition, no complex scheduling algorithm is required with the second method. Further, when the user operates in certain modes such as the "P2" mode of operation for basic packet data service, the forward link continuity and outer-loop power control are maintained by the F-DCCH, and so the F-DCCH becomes unsharable in this mode. As a result, the second approach is supported in IS-95C.

It should be noted that if the signaling data is always transmitted in the physical layer on the F-DCCH regardless of whether it is valid or not in the link layer, then capacity due to invalid signaling data is wasted. To make use of the system capacity efficiently, the signaling activity may be exploited. That is, when signaling data is invalid or does not exist in the link layer, its power is removed from the signaling channel, i.e., discontinuous transmission (DTX) is employed in IS-95C.

The F-DCCH optionally may be used in soft handoff mode. If MAC messages are transmitted on the F-DCCH in a certain service mode, the control of MAC is centralized if the F-DCCH is employed in soft handoff mode, otherwise, MAC control is distributed when not in soft handoff mode.

IS-95C F-DCCH Information

The signaling data carried by the IS-95C F-DCCH corresponding to different modes and services are given below.

- In the "V1" mode for voice services, the F-DCCH is not used.
- In the "V2" mode for voice services, the Upper Layer Signaling frames (General Handoff Direction Message, In-Traffic Systems Parameters Message, Neighbor List Update Order. Local Control Order, etc.) are sent on the F-DCCH.
- In the "P1" mode for packet data service, the F-DCCH is not used.
- In the "P2" mode for packet data service, the Upper Layer Signaling messages and MAC messages are sent on the F-DCCH.
- In the "P3" mode for packet data service, the MAC messages are sent on the F-DCCH.
- In the "VP1" mode for concurrent voice and packet data service, the F-DCCH is not used.

- In the "VP2" mode for concurrent voice and packet data service, the Upper Layer Signaling messages and MAC messages are sent on the F-DCCH.

To support the mixing of MAC signaling with RLP frames or Upper Layer Signaling information, the F-DCCH supports dual frame size operation (5 and 20 ms).

Basic TIA/EIA-95, TIA/EIA-95-B Soft Handoff Procedures

IS-95 specifies the procedures for a MS to send a Pilot Strength Measurement Message (PSMM) to the Base Station based on a set of fixed thresholds, i.e. T_ADD, T_DROP and T_COMP. The PSMM from the MS to the BS is triggered as pilots cross such thresholds. In particular, the MS sends a PSMM when it finds a pilot of sufficient strength (i.e., pilot strength exceeding T_ADD) which is not in the Active Set (i.e., the pilots associated with the Forward Traffic Channels being demodulated by the MS) of the MS. From the BS viewpoint, the PSMM is a request from the MS to add the new pilot in its active set. The BS on receiving the PSMM may use some algorithm (using the reported pilot strengths) to decide on whether the Active Set pilots should be changed for soft handoff.

Since it was observed based on field data that excessive soft/softer handoff in an IS-95 system has negative impact on system capacity and network resources, several changes were made to the soft handoff procedures in TIA/EIA-95-B standard to improve performance. The improved soft handoff (ISH) feature specified in TIA/EIA-95-B is intended to reduce the percentage of time that the MS is in soft handoff without impacting the system performance. The principal benefit of the ISH feature is, thus, to reduce unnecessary handoff legs so as to improve efficiency in both capacity and resource allocation due to soft handoff.

In TIA/EIA-95-B, the ISH feature enables the MS to use dynamic thresholds, which the pilot strengths of new pilots need to cross, based on the combined pilot strength of the current Active Set pilots as a trigger to send the PSMM to the BS. Specifically, the MS sends a PSMM (add pilot request) when the pilot strength (PS) of any pilot in the Neighbor Set or Remaining Set satisfies:

$$10\times\log_{10} PS > \max\left(\frac{SOFT\_SLOPE}{8}\times 10\times\log_{10}\sum_{i\in A} PS_i + \frac{ADD\_INTERCEPT}{2}, \frac{T\_ADD}{2}\right)$$

where the summation is performed over all pilots currently in Active Set; SOFT_SLOPE, ADD_INTERCEPT are BS configurable parameters (sent by BS to MS in certain Overhead or Traffic Channel Messages). Thus, this feature enables the MS to *screen* candidate pilots before sending in a request for adding them to or removing them

from the Active Set based on the combined pilot strength of the Active Set pilots. The quantity on the RHS of the above inequality will be denoted by T_dyn_ADD.

Current IS-95/IS-95-B Performance

For IS-95/IS-95B systems, unlike most other messages, reliable reception of the Handoff Direction Message *(HDM)* by the mobile is critical. In many cases the *HDM* is the weakest link in a call; failure of the mobile to receive the *HDM* can result in a dropped call.

In particular, one of the problem areas in IS-95/IS-95-B based systems has been the fast rising pilot scenario. In this scenario, the MS detects a fast rising pilot which does not belong to its Active Set and sends a PSMM to the BS. The BS processes this request from the MS and after some latency sends a Handoff Direction Message. However, during this time, the pilot strength of the new pilot may have significantly risen and the resulting interference may be extremely serious. This may cause the MS to lose the Handoff Direction Message sent by the BS, and may eventually result in a dropped call. Clearly a scheme which increases the reliability with which the MS receives the Handoff Direction Message from the BS can significantly reduce the call drop probability in such scenarios.

Controlling Early Code Channel Assignment

In the *Early Code Channel Assignment* embodiment illustrated in Fig. 3, the BS 112 processes the PSMM from the MS 116 and speedily assigns a Walsh code channel for the F-DCCH so that the MS 116 can use the F-DCCH in soft handoff as soon as possible. The BS 112 assigns a Walsh function to the MS 116. The F-DCCH is in soft handoff mode prior to assignment of the Walsh function for the F-DTCH, which is already in soft handoff for the same MS. This speedy assignment of the Walsh function for the F-DCCH vis-a-vis the F-DTCH is carried out by skipping some of the BS procedures which may be unnecessary with respect to the signaling data carried by the F-DCCH. For example, on receiving the PSMM from the MS 116, the BS 112 optionally may assign a Walsh function to the MS 116 at a new sector/cell A (not shown) for the F-DCCH unconditionally, thus skipping most of the selector processing of the PSMM.

The assigned Walsh function for the F-DCCH in a new cell/sector A may be conveyed by the BS 112 to the MS 116 via the new Early General Handoff Direction Message (EGHDM) in step 308 of the timeline. From the MS 112 point of view, the early F-DCCH channel assignment is simply a recommendation to start reception of the messages (such as GHDM) carried by the F-DCCH on the specified code channel. It is

desirable for the BS to convey a time interval T_dcch to the MS 112 in the EGHDM. The MS 112 begins a timer on receiving the EGHDM in step 310. As soon as the timer value exceeds T_dcch in step 312, the MS 112 measures the pilot strength Ec/Io of the pilot A (not shown). At this time, if the pilot strength of the pilot A exceeds the appropriate soft handoff threshold in IS-95B, the MS begins to use the pilot A in its Active Set for the F-DCCH. Alternatively, if the pilot strength of the pilot A is below the appropriate soft handoff threshold in IS-95B, the MS does not add the pilot A in its Active Set for the F-DCCH. The timing diagram in Fig. 3 further illustrates this technique by denoting C as a (strong) Neighbor Set pilot of a MS with pilot strength (in dB) PS_C in step 314.

Another embodiment is to reserve a code channel for the F-DCCH in a cell/sector for each MS 112 in a neighboring sector. This code channel reservation scheme is based on predetermined parameters specific to the MS (and optionally cell).

Controlling Early Signaling from MS

Referring now to Fig. 4,in the *Early Signaling from MS* embodiment, the pilot signal at the MS 116 is measured in step 404. The MS 116 sends an early PSMM to the BS 112 primarily as a request from the MS 116 to the BS 112 to add a new pilot A in its Active Set for the F-DCCH in step 406. This optionally is followed by another PSMM at a later time as a request from the MS to the BS to add the pilot A in its Active Set for the F-DTCH as well. Thus, the MS 116 is enabled to have the F-DCCH at the new pilot in soft handoff as soon as possible for reliable reception of signaling data from the BS 112.

The soft handoff improvements introduced in IS-95B are directed in part to increase capacity when data rates may be high on the forward link (FL). However, the message rate on the F-DCCH may be significantly lower than the data rate on the traffic channel. Thus, having the signaling channel in early soft handoff may not impact FL capacity significantly. Further, it should be noted that having the F-DTCH at the new pilot in soft handoff right after Early Signaling from MS may be inefficient if a code channel is allocated when not necessary.

Several options exist to have the MS transmit early PSMM signaling to have the F-DCCH in early soft handoff. One embodiment is by manipulating the IS-95B soft handoff parameters or even the soft handoff procedure itself. An example of one such example is given next.

The BS includes a new ADD_INTERCEPT_dcch field in the Extended System Parameters Message (ESPM) and in the Handoff Direction Messages (such as GHDM) in addition to the ADD_INTERCEPT field as described earlier. The MS 112 sends a

PSMM (add pilot for F-DCCH request) when the pilot strength (PS) of any pilot in the Neighbor Set or Remaining Set satisfies:

$$10\times\log_{10} PS > \max\left(\frac{SOFT\_SLOPE}{8}\times 10\times\log_{10}\sum_{i\in A} PS_i + \frac{ADD\_INTERCEPT\_dcch}{2}, \frac{T\_ADD}{2}\right)$$

where the summation is performed over all pilots currently in Active Set; SOFT_SLOPE, ADD_INTERCEPT are BS configurable parameters (sent by BS to MS in certain Overhead or Traffic Channel Messages). The quantity on the RHS of the above inequality will be denoted by T_dyn_ADD_dcch as in step 404. By having

$$ADD\_INTERCEPT\_dcch < ADD\_INTERCEPT$$

the MS 112 may send an early PSMM signal requesting the BS 116 to add the new pilot in its Active Set for the F-DCCH as in step 406.

Again, the assigned Walsh function for the F-DCCH in a new cell/sector A may be conveyed by the BS 116 to the MS 112 via the EGHDM message in step 408. Again, the BS may convey a time interval T_dcch to the MS in the EGHDM and the MS begins a timer on receiving the EGHDM in step 410. When the timer value exceeds T_dcch in step 412, the MS 116 measures the pilot strength Ec/Io of the pilot A. In step 414, if the pilot strength of the pilot A exceeds the above dynamic soft handoff threshold (using ADD_INTERCEPT_dcch as above), the MS 116 begins to use the pilot A in its Active Set for the F-DCCH. Alternatively, if the pilot strength of the pilot A is below the above soft handoff threshold in IS-95B, the MS does not add the pilot A in its Active Set for the F-DCCH. Denoting C as a (strong) Neighbor Set pilot of a MS with pilot strength PS_C (in dB). In step 416, the MS 116 sends a PSmm while in step 418 BS 112 sends a GHDM over DCCH.

Advantageously, no internal Base Station procedure need be skipped if the Early Signaling from MS method is used in contrast to the case when the Early Code Channel Assignment method was used.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WE CLAIM:

CLAIMS

1. A method of initiating a handoff in a wireless communication system among a mobile station and a plurality of cells, comprising the steps of:
transmitting a first pilot strength measurement message from a mobile station to a base station;
assigning a Walsh code channel for a first forward link dedicated control channel;
assigning a Walsh function to the mobile station to provide early soft handoff capability to a first forward dedicated traffic channel; and
transmitting a first message type (eghdm) from a base station to a mobile station containing information to start reception by the mobile station on the forward dedicated control channel of said first message.

2. The method as in claim 1 further including the step of :
conveying a predetermined time interval to the mobile station within said first message type.

3. The method of claim 2 further including the step of:
starting a timer based on a time of reception of said first message type.

4. The method of claim 3 further including the steps of:
incrementing the timer until its value exceeds a predetermined threshold (t_dcch);
measuring a received pilot signal strength; and
if said received pilot signal strength exceeds a predetermined (IS95B) threshold, adding the associated pilot to an Active set for a forward dedicated control channel.

5. A method of initiating a handoff in a wireless communication system among a mobile station and a plurality of base stations, comprising the steps of:
transmitting a first pilot strength measurement message from a mobile station to a base station to add a new pilot to its active set for a forward data control channel; and
optionally transmitting at least one additional pilot strength measurement signal from the mobile station to the base station to add a pilot to its active set for a forward dedicated traffic channel.

6. The method of claim 5 further including the step of:
adding a field in a first message (ESPM) and second message (GHDM) when a measured pilot strength in a predetermined group exceeds a calculated threshold.

7. The method of claim 6 wherein said predetermined group is one of neighbor set and remaining set.

8. The method of claim 7 wherein the measured pilot strength satisfies:

$$10\times\log_{10} PS > \max\left(\frac{SOFT\_SLOPE}{8}\times 10\times\log_{10}\sum_{i\in A} PS_i + \frac{ADD\_INTERCEPT\_dcch}{2}, \frac{T\_ADD}{2}\right);$$

wherein the summation is performed over all pilots in an active set, and SOFT_SLOPE and ADD_INTERCEPT are base station configurable parameters.

9. The method as in claim 8 further including the step of : conveying a predetermined time interval to the mobile station within said first message type.

10. The method of claim 9 further including the step of: starting a timer based on a time of reception of said first message type.

11. The method of claim 10 further including the steps of: incrementing the timer until its value exceeds a predetermined threshold (t_dcch); measuring a received pilot signal strength; and if said received pilot signal strength exceeds a predetermined (IS95B) threshold, adding the associated pilot to an Active set for a forward dedicated control channel.

12. An apparatus for initiating a handoff in a wireless communication system among a mobile station and a plurality of cells, comprising:
means for transmitting a first pilot strength measurement message from a mobile station to a base station;
means for assigning a Walsh code channel for a first forward link dedicated control channel;
means for assigning a Walsh function to the mobile station to provide early soft handoff capability to a first forward dedicated traffic channel; and
means for transmitting a first message type (eghdm) from a base station to a mobile station containing information to start reception by the mobile station on the forward dedicated control channel of said first message.

13. The apparatus as in claim 12 further including: means for conveying a predetermined time interval to the mobile station within said first message type.

14. The apparatus of claim 13 further including:

means for starting a timer based on a time of reception of said first message type.

15. The apparatus of claim 14 further including: means for incrementing the timer until its value exceeds a predetermined threshold (t_dcch); means for measuring a received pilot signal strength; and means for adding the associated pilot to an Active set for a forward dedicated control channel if said received pilot signal strength exceeds a predetermined (IS95B) threshold.

16. An apparatus of initiating a handoff in a wireless communication system among a mobile station and a plurality of base stations, comprising: means for transmitting a first pilot strength measurement message from a mobile station to a base station to add a new pilot to its active set for a forward data control channel; and means for optionally transmitting at least one additional pilot strength measurement signal from the mobile station to the base station to add a pilot to its active set for a forward dedicated traffic channel.

17. The apparatus of claim 16 further including: means for adding a component to a first message (ESPM) and second message (GHDM) when a measured pilot strength in a predetermined group exceeds a calculated threshold.

18. The apparatus of claim 17 wherein said predetermined group is one of neighbor set and remaining set.

19. The apparatus of claim 18 wherein the measured pilot strength satisfies:

$$10\times\log_{10} PS > \max\left(\frac{SOFT\_SLOPE}{8}\times 10\times\log_{10}\sum_{i\in A} PS_i + \frac{ADD\_INTERCEPT\_dcch}{2}, \frac{T\_ADD}{2}\right);$$

wherein the summation is performed over all pilots in an active set, and SOFT_SLOPE and ADD_INTERCEPT are base station configurable parameters.

20. The apparatus as in claim 8 further including: means for conveying a predetermined time interval to the mobile station within said first message type.

21. The apparatus as in claim 9 further including: means for starting a timer based on a time of reception of said first message type.

22. The apparatus of claim 21 further including:

means for incrementing the timer until its value exceeds a predetermined threshold (t_dcch);

means for measuring a received pilot signal strength; and

means for adding the associated pilot to an Active set for a forward dedicated control channel if said received pilot signal strength exceeds a predetermined (IS95B) threshold.

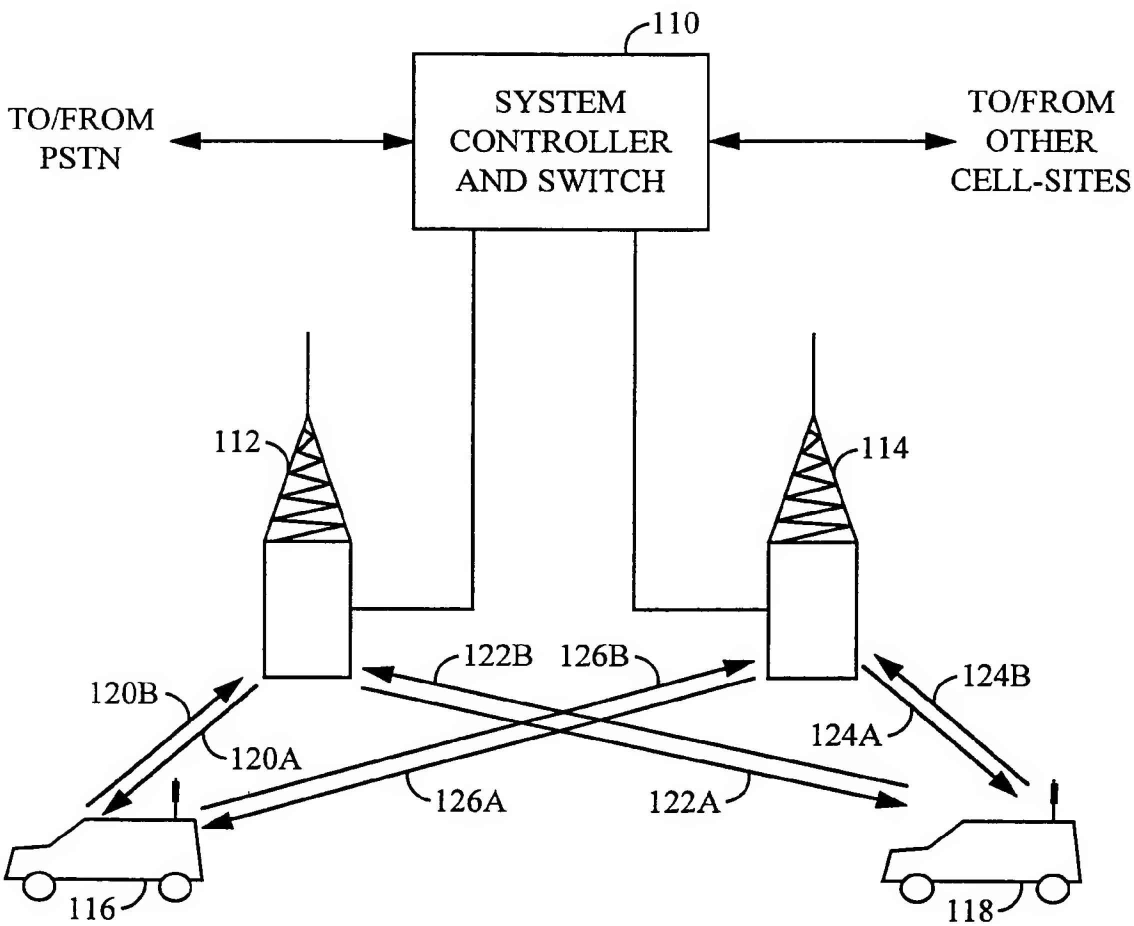
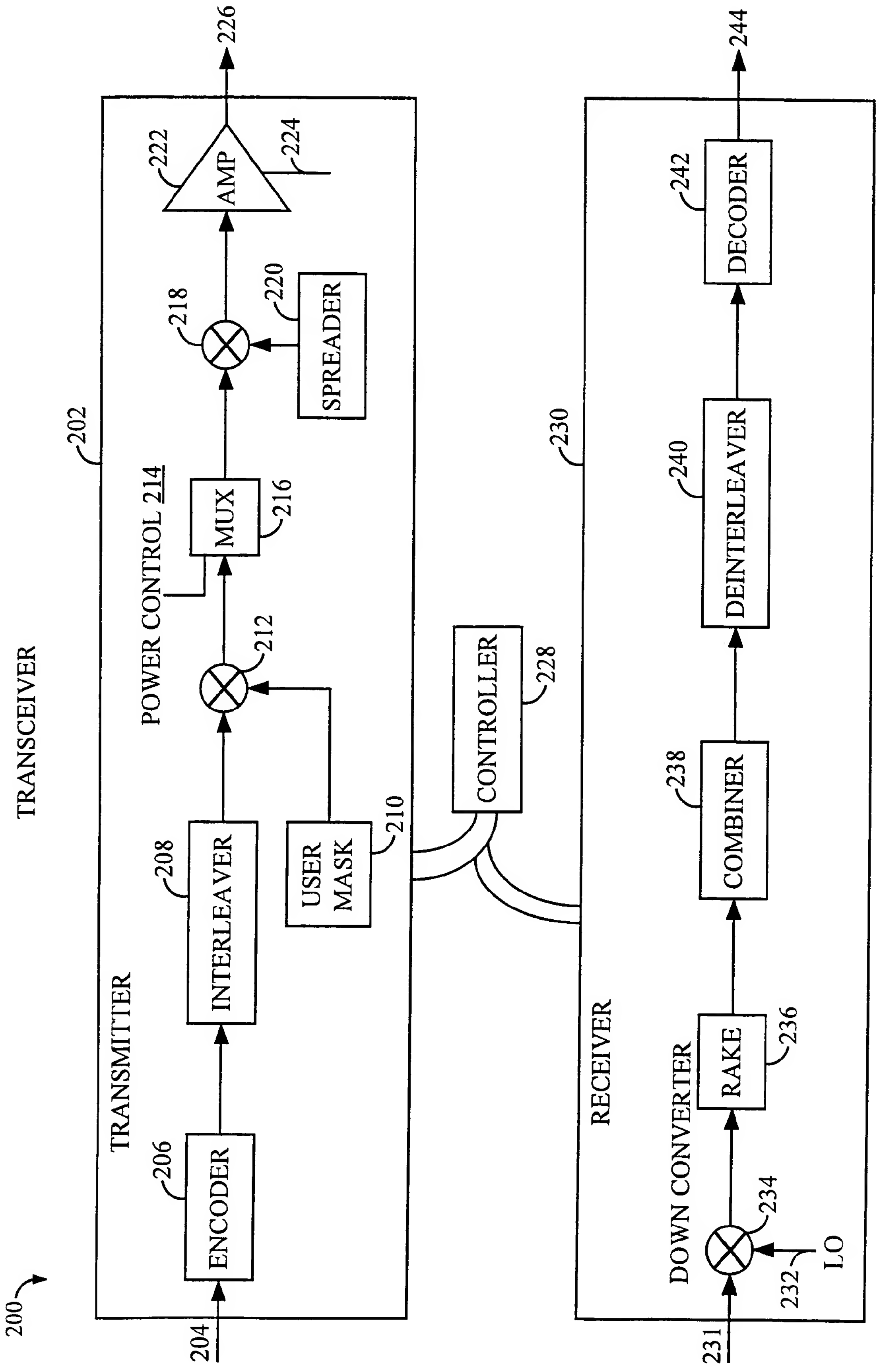

110
SYSTEM CONTROLLER AND SWITCH
TO/FROM PSTN
TO/FROM OTHER CELL-SITES
112
114
120B
120A
122B
126B
124B
124A
126A
122A
116
118

FIG. 1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200
TRANSMITTER
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204
ENCODER
206
INTERLEAVER
208
USER MASK
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POWER CONTROL 214
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216
218
SPREADER
220
AMP
222
224
226
CONTROLLER
228
RECEIVER
230
231
LO
232
DOWN CONVERTER
234
RAKE
236
COMBINER
238
DEINTERLEAVER
240
DECODER
242
244

FIG. 2

FIG. 3: TIMING DIAGRAM ILLUSTRATING EARLY CODE CHANNEL ASSIGNMENT METHOD

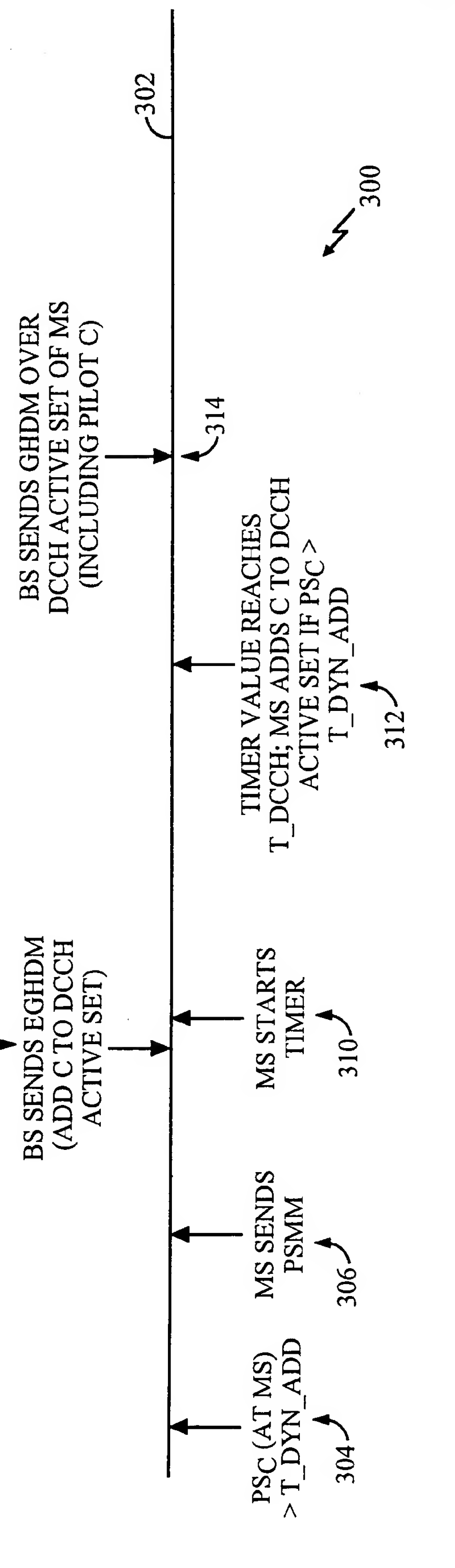
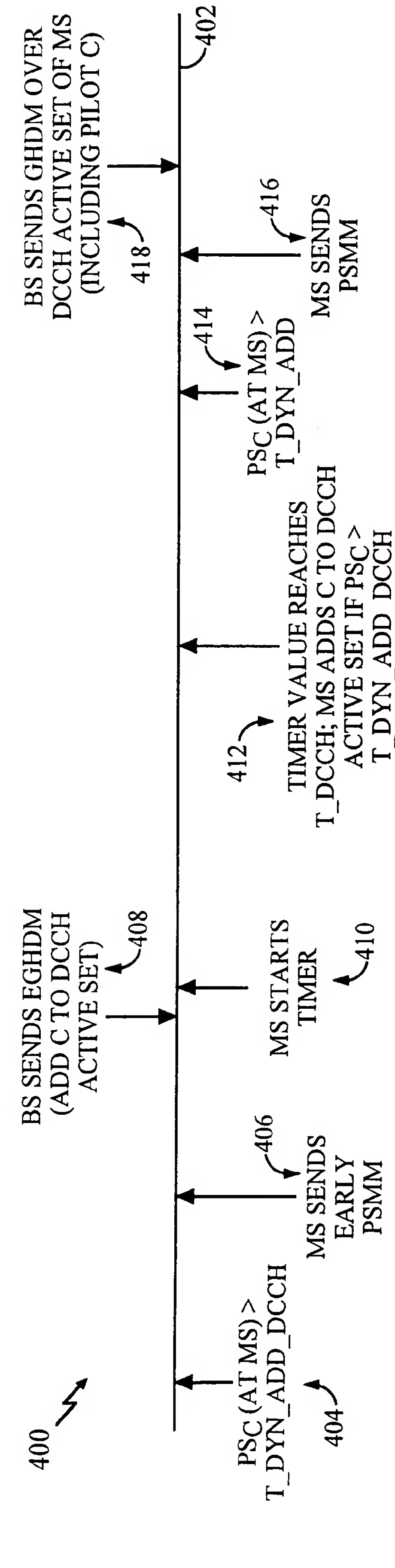


FIG. 4: TIMING DIAGRAM ILLUSTRATING EARLY SIGNALING FROM MS METHOD



INTERNATIONAL SEARCH REPORT

Intern ıal Application No
PCT/US 00/14233

A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 35525 A (QUALCOMM INC) 13 August 1998 (1998-08-13) page 3, line 35 - line 39 page 5, line 14 - line 35 page 8, line 35 - line 36 page 10, line 38 -page 11, line 30	1,5,6, 12,16,17
Y	page 12, line 16 - line 23	7,8,18, 19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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21 August 2000	12/09/2000

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	"MOBILE STATION-BASE STATION COMPATIBILITY STANDARD FOR WIDEBAND SPREAD SPECTRUM CELLULAR SYSTEMS" TIA/EIA STANDARD,ANSI/TIA/EIA-95-B, 3 February 1999 (1999-02-03), pages 6-380,6-381,7-133,7-301,7-302,7-303,7-304, 7-305-7-306,7-307,b-8, XP002145331 page 6-381, line 5 - line 9 page 7-133, line 28 - line 32 page 7-306, line 31 - line 33 page 7-307, line 13 - line 17 -----	7,8,18, 19

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/14233

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9835525 A	13-08-1998	US 5987326 A	16-11-1999
		AU 6322798 A	26-08-1998
		CN 1247682 T	15-03-2000
		EP 0960547 A	01-12-1999

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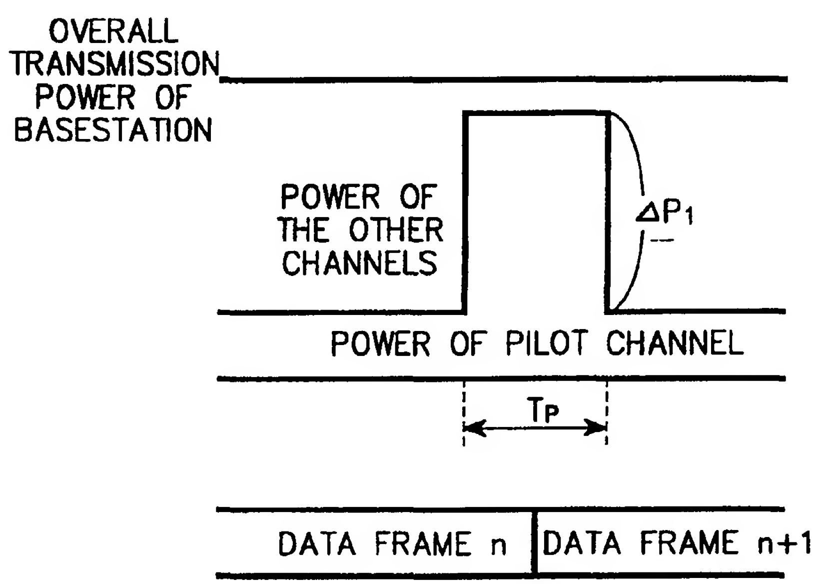
(54) Title: CHANNEL COMMUNICATION APPARATUS AND METHOD IN CDMA COMMUNICATION SYSTEM

(57) Abstract

A channel communication apparatus and method are provided for a CDMA communication system method for acquiring signals from multiple adjacent base stations by a terminal; for providing more efficient set management; for providing more efficient multipath acquisition and finger assignment; and for acquiring a signal sent from an adjacent base station and a multipath signal which can reduce power consumption and hardware complexity in the terminal. The apparatus and methods also accurately measure the power or time delay of a signal received from a base station by a terminal in a CDMA communication system.



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CHANNEL COMMUNICATION APPARATUS AND METHOD IN CDMA COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to cellular communication systems. More particularly, the present invention relates to a device and method in a CDMA (code division multiple access) communication system for performing channel acquisition, set maintenance, location positioning, multipath detection, delay estimation, channel status estimation and finger assignment after detecting a specific channel on a forward link.

2. Description of the Related Art

FIG. 1 illustrates the various power levels associated with signals on a forward link transmitted by a base station in a conventional CDMA communication system (i.e., IS-95). The forward link is comprised of a pilot channel, a sync channel, a paging channel, a control channel and a traffic channel. The traffic channel is a dedicated channel, whereas the synch channel, the paging channel, and the control channel are common channels. Traffic signals are sent on traffic channels at different transmission power levels, and a sync signal and a pilot signal are sent on the synch channel and the pilot channel at constant transmission power levels. A terminal in this system acquires initial synchronization from the pilot channel received at the constant power level, and then performs finger assignment

and set maintenance for handoff by measuring the reception level of the pilot channel. During the set management, the terminal can manage signal information generated from a plurality of base stations by continuously monitoring pilot signals received from a candidate set and a neighbor set as well as from an active set in communication with the terminal. Here, the terminal measures the reception level and delay or relative delay of multipath signal components received from the base stations. If the signal level of a pilot signal received from a base station in the active set drops to T_Drop or below during a call or the signal level of a pilot signal received from a base station in the neighbor set rises to T_Add or higher during a call, the terminal sends a pilot level measurement message to the base station. Upon reception of the message, the addressed base station considers that a handoff occurs and sends a handoff message to the terminal. Through a series of procedures, the terminal implements a handoff as it is travelling.

Windows are set for base stations and the terminal searches a corresponding window for each base station. As the bandwidth of a CDMA communication system becomes wider as in IMT (International Mobile telecommunication)-2000, the time resolution in a receiver becomes correspondingly narrower. Thus, the chip size of a window which the terminal should monitor becomes larger. Further, energy received from one path may be smaller than in an existing narrow-band system by the amount of increased time resolution. Further, if the rate of a pilot channel relative to all other transmission signals is to be reduced due to the wide band, a significant constraint is imposed on the mobile search. Therefore, as a consequence of the implementation of a wideband system, the power of the pilot channel cannot be reduced to or below a predetermined rate.

IMT-2000 supports a high data rate service as compared to the conventional mobile communication system. To accommodate rapid data transmission, a signal

should be sent at a higher power level than a low data rate service like voice. Since transmission of a signal at a high power level may adversely affect the entire system capacity in a CDMA communication system, it is necessary to limit available services according to terminal location and channel status. This is performed through the conventional set management. However, the conventional set management has limitations because it is based on a low data rate service. To overcome the limitations associated with conventional set management, a way should be explored in which a terminal can acquire signals from more base stations and estimate the channel status faster and more accurately.

The FCC (Federal Communications Commission) of the United States provides that a terminal should be equipped with a device for informing a user믤 location within a radius of 125m for 67% or more time in an emergency. If a terminal can acquire signals from a plurality of base stations during a set management, the signals can help detect the mobile's location. As signals are acquired from more base stations in a neighbor set, the location can be detected more accurately.

However, it is impossible for a terminal nearer to a base station to acquire a signal from another base station because a signal from the former is far stronger than that the latter. Even a terminal located within a handoff region has much difficulty acquiring signals from a plurality of base stations because the power of a pilot channel sent from each base station on a forward link is limited. FIG. 2 illustrates, by example, power measurements of pilot signals sent from a plurality of base stations. Even a terminal near a handoff region cannot distinguish a pilot signal from noise component because of insufficient transmission power of the pilot signal. In this case, a searcher in the terminal detects the pilot signal only if it despreads an input signal for a long time. To accurately and rapidly acquire the

pilot signal, the terminal should be provided with a searcher with complex hardware.

In view of the foregoing, it is not easy to estimate the location of a terminal on a forward link. To overcome this problem, an IS-95 system estimates a terminal's location using a power-up function (PUF). To allow the location of a terminal in an emergency to be estimated, the terminal sends a signal on a reverse link at a high power level until a plurality of base stations receive the signal. FIG. 3 illustrates the mobile initiated signal. Upon receipt of a PUF command from a base station, the terminal raises its transmission power until a plurality of base stations can acquire its signal. The base station acquires the signal from the terminal and measures a round trip delay and signal level. Based on the measured information, the distance between the terminal and a corresponding base station can be estimated.

Upon receipt of a command requesting implementation of a PUF from the base station, the terminal sends the PUF using a preamble of a reverse traffic channel as shown in FIG. 3. The base station sets PUF performing positions, intervals between PUF pulses PUF-PERIOD, and other related parameters, and the terminal sends the PUF at the determined locations at a power level INC_PWR for the first pulse and then at a power level a specified amount PWR_STEP higher than the previous power level for a next pulse. The maximum number of pulses that the terminal can send is determined by a parameter TOTAL_PUF. The period of A single PUF is an integer multiple of 16 PCGs and divided into three segments the segments PUF_SETUP_SIZE and INC_PUF_SIZE are sent at a usual power level but the segment COMPLETE_FRAME is sent at a higher power level than usual.

To enable multiple base stations to receive a mobile signal, there are cases

where the power of a reverse link should be increased from that for a call by 30-40dB or higher. This may have a deadly influence on the performance and capacity of the reverse link. In addition, a mobile PUF is limited by a maximum mobile transmission power. The PUF scheme has limitations in its effectiveness of estimating a mobile location if a terminal is positioned where the distance between the terminal and base stations is large or the terminal runs out of battery life.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide a method of acquiring signals from multiple adjacent base stations by a terminal in a CDMA communication system.

Another object of the present invention is to provide a more efficient set management method in a CDMA mobile communication system.

Still another object of the present invention is to provide a more efficient multipath acquisition and finger assignment method in a CDMA communication system.

Another object of the present invention is to provide a method of acquiring a signal sent from an adjacent base station and a multipath signal, which can reduce power consumption and hardware complexity in a terminal in a CDMA communication system.

A still further object of the present invention is to provide a method of accurately measuring the power or time delay of a signal received from a base station by a terminal in a CDMA communication system.

Yet still another object of the present invention is to provide a method of reducing the size and power consumption of a memory when a terminal stores an input signal for processing in a CDMA mobile communication system.

A further object of the present invention is to provide a method of increasing the entire system capacity by reducing a usual pilot power and increasing a pilot power for a short time in a CDMA communication system.

Another object of the present invention is to provide a method of estimating the location of a terminal via a forward link in a CDMA communication system.

To achieve the above objects, there is provided a signal transmitting method in a base station. A first signal on a common channel and a pilot signal on a pilot channel are sent at predetermined power levels, and the pilot signal is sent at a higher level than the predetermined level for a predetermined time period. A second signal on a dedicated channel is sent at a different level according to the number of subscribers.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIG. 1 illustrates the structure of a forward link directed from a base station to a mobile station in a conventional mobile communication system;

FIG. 2 illustrates measurements of signals received from an active set and a neighbor set by a conventional terminal;

FIG. 3 illustrates mobile output when a conventional PUF is used;

FIGs. 4A and 4B illustrate a forward link on which the power of a pilot channel is instantaneously raised so that a terminal can acquire signals from a plurality of base stations according to embodiments of the present invention;

FIGs. 5A and 5B illustrate example of increased pilot channel power when there are a plurality of base stations;

FIG. 6 is a view referred to for exemplarily illustrating effects of increasing the pilot channel power according to the embodiments of the present invention;

FIG. 7 illustrates a method of distributing the transmission power of a base station when a pilot channel is sent at divided power levels using a plurality of different spreading codes;

FIG. 8 is a block diagram of a transmitting device in a base station, for separately sending a pilot channel using a plurality of spreading codes;

FIGs. 9A and 9B illustrates an example where the entire transmission power of a base station drops for a time period Tp;

FIG. 10A illustrates an example where a plurality of base stations concurrently drop their entire transmission powers;

FIG. 10B illustrates an example where a plurality of base stations drop their entire transmission powers by turns;

FIG. 10C illustrates an example where a plurality of base stations stop transmission of signals for a specified time period;

FIGs. 11A and 11B illustrate examples where both the increase of pilot power and the decrease of the entire transmission power concurrently occur;

FIG. 12 is a block diagram of a searcher of a receiver in a terminal according to an embodiment of the present invention;.

FIG. 13 is a block diagram of a despreader in the searcher of FIG. 12;

FIG. 14 is a block diagram of a first embodiment of a despreader in a receiver of a terminal;

FIG. 15 is a block diagram of a second embodiment of the despreader in the

receiver of the terminal;

FIG. 16 is a block diagram of a third embodiment of the despreader in the receiver of the terminal;

FIG. 17 is a block diagram of a fourth embodiment of the despreader in the receiver of the terminal;

FIG. 18 illustrates a mobile operation for searching adjacent frequencies;

FIGs. 19A to 19D illustrate another embodiment of a forward link for enabling a terminal to acquire signals from a plurality of base stations by instantaneously increasing the power of a specific data channel;

FIGs. 20A and 20B illustrate an embodiment of increasing the power of a specific data channel when there are a plurality of base stations;

FIG. 21 is a block diagram of a transmitting device in a base station, for controlling the power of a specific data channel for a predetermined time period prior to transmission;

FIG. 22 illustrates an embodiment of dropping the overall transmission power of a base station , for a predetermined time period Td;

FIG. 23A illustrates another embodiment of simultaneously dropping the overall transmission power in a plurality of base stations;

FIG. 23B illustrates a further embodiment of dropping the overall transmission power in a plurality of base stations by turns;

FIGs. 24A and 24B illustrates still another embodiment where both the increase of the data channel power and the decrease of the overall transmission power concurrently occur; and

FIG. 25 illustrates a terminal operation for searching for an adjacent frequency according to the embodiments related with FIGs. 19 to 24B.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described in detail referring to the attached drawings. Like reference numerals denote the same components and it is to be noted that a detailed description of a known function or structure of the present invention will be omitted if it is deemed to obscure the subject matter of the present invention.

In accordance with an embodiment of the present invention, a base station sends a pilot signal on a forward pilot channel at an increased power level for a specified time period in order to allow efficient search in a terminal. The terminal despreads the received signal at the higher power level for a specified time period, detects signals from a plurality of base stations, and measures the signal level, delay, or delay relative to other paths of a multipath signal received from each base station.

It should be noted that the following description of the present invention refers to the other channels except for the pilot channel, that is the sync channel, the paging channel, the control channel, and the traffic channel as data channels. Also, data frames mentioned hereinbelow are included in a traffic signal on the traffic channel.

FIGs. 4A and 4B illustrate the structure of a forward link according to embodiments of the present invention. Here, a base station sends a pilot signal at an instantaneously increased power level so that a terminal can acquire pilot signals from a plurality of base stations. The forward channels include the pilot channel, the sync channel, the paging channel, the control channel, and the traffic channel.

Referring to FIG. 4A, the base station increases the power of the pilot signal on the pilot channel from its usual power level by $\Delta P1$ for a predetermined time

period Tp. In this embodiment, the entire transmission power of the base station is not changed. That is, signals on some data channels are sent at a decreased transmission power level or are not sent, and the rest of the available power is assigned to the pilot signal on the pilot channel. As such, the power of the pilot signal is higher than usual for the short time Tp. For more efficient set management, the entire transmission power of the base station may be assigned to the pilot channel for Tp.

The pilot signal can be transmitted at the predetermined time interval Tp only. That is, the pilot power level can be set to 0 except the predetermined time period Tp. The pilot power level increment _P1 can be proportional to the power level of normal pilot channel, if the channel exists.

FIG. 4A shows a case where signals on some data channels are sent with low power or not sent for a time period defined by Tp. Also, Tp is specified at the boundary between two data frames. This is intended to prevent performance degradation of a single frame caused by transmission of a data channel signal at a lower power level than usual. In addition, Tp is preferably located over two consecutive data frames, with Tp/2 over each data frame, for uniform performance of the two data frames. The terminal which acquires synchronization should already know the value specified Tp and its location with respect to the data frames.

Tp can vary with the propagation environment of the base station, arrangement of base stations, and signal bandwidth. For larger values of Tp (i.e., longer in time), a higher gain is obtained. In addition, for larger values of Tp, the terminal can even acquire a pilot signal transmitting at a lower power. However, there exists an upper bound in that if Tp is too long, the pilot signal on the pilot channel occupies the power which otherwise would be assigned to transmit data,

resulting in a decrease in system capacity. Therefore, the system needs to adjust Tp according to the system environment. For example, assuming that a system has a chip rate of 3.6864Mcps (mega chips per second), a data frame is 20ms in duration, and Tp includes 2048 chips, Tp is determined to be 0.55ms in duration. In the embodiment illustrated in FIG. 4A, Tp is equally divided over the two frames and thus the power of the pilot signal is higher than usual for 0.28ms (=0.55ms/2) over each data frame. This is a very short period, that is, 1.4% of a 20ms data frame. The resulting degradation of the forward link performance is negligibly small.

FIG. 4B shows another embodiment of increasing the power of a pilot signal on the pilot channel for a time period Tp. Here, data channel signals are sent for a time Tp, the entire transmission power of the base station is increased by an amount ΔP2 for the duration of the transmission, Tp. The pilot signal power is increased by ΔP1 for Tp. Here, ΔP2 and ΔP1 may be equal or different. That is, this embodiment is characterized by the concurrent increase of the entire transmission power of the base station and the pilot signal power. As a result, the rates of the pilot signal power and the overall transmission power of the base station are temporarily increased from their ordinary levels. Assuming that a usual overall transmission power density of the base sation is Ior and energy per chip of the pilot signal on the pilot channel is Ec,

$$\frac{pilot\ Ec + \Delta P_1}{Ior + \Delta P_2} > \frac{\text{pilot Ec}}{\text{Ior}} \qquad (1)$$

Equation 1 illustrates the fact that the ratio of the pilot signal power to the overall transmission power of the base station is instantaneously higher than usual.

It should be noted that it is feasible for the power of the pilot signal on the

pilot channel to rise to the usual overall transmission power of the base station (i.e., usual overall transmission power +ΔP2). In this case, the base station transmits only the pilot signal and punctures other data channels.

The embodiment of FIG. 4B is the same as that of FIG. 4A in that Tp is located at the data frame boundary, and the terminal should know the value of Tp and its location. Tp can be periodic or determined by the base station.

If there are a plurality of base stations around a terminal, the base stations are synchronized with respect to Tp so that the base stations can increase the power of their respective pilot signals concurrently. It is further contemplated that the base stations can otherwise increase their pilot signal powers alternately. The time period Tp when each base station increases its pilot signal power can be periodic or determined by the base station.

FIGs. 5A and 5B illustrate operations of base stations with a plurality of timings synchronized. In the drawings, only pilot signal power is shown. Here, the overall transmission power of a base station can be maintained at a usual level or increased by ΔP2 as shown in FIG. 4A. The significant thing is that the ratio of the pilot signal power to the overall transmission power of the base station is instantaneously higher than usual.

FIG. 5A illustrates an embodiment where each base station increases its pilot signal power at a different time. Which base station sends a pilot signal at a higher power level and at what time are preset between the terminal and the base stations. Since the terminal can identify a base station which sends its pilot signal at a higher power level, it despreads the corresponding pilot signal of an input signal and measures the reception level of the pilot signal. For this purpose, a widely used

serial searcher or a matched filter can be used. Use of the serial searcher reduces hardware complexity but requires a long Tp, adversely affecting system capacity. On the other hand, despite increased hardware complexity, the matched filter can vastly reduce Tp, which is beneficial to system capacity. Furthermore, an input signal can be stored in a memory prior to despreading. With this scheme, Tp can be shorter without increasing receiver complexity. The structure of a receiver having the advantage according to the present invention will be described later with reference to FIG. 12.

In FIG. 5A, one base station increases the power of a pilot signal on a pilot channel, and the other base stations maintain the power of pilot channels at a usual level. It is also contemplated that base stations may be divided into groups, where one or more groups of base stations may be made to increase the power of a pilot channel. For example, if the totality of base stations define a set S, the set S may be divided into a plurality of subsets S1, S2, ..., SM. Then, base stations within a subset would increase pilot power for a specified time period and the other base stations maintain pilot power at their usual level. The subsets S1, S2, ..., SM can be designed such that there are not any intersections between subsets, or vice versa.

FIG. 5B illustrates another embodiment of an operation according to the present invention directed to a plurality of base stations. In FIG. 5B, the plurality of base stations concurrently increase the power of a pilot signal on a pilot channel. An agreement is made between a terminal and the base stations on when to increase the power of the pilot signal from the usual level. Since the terminal knows which base station will send a pilot signal at a higher level, it despreads an input signal with a spreading code for a corresponding pilot channel and measures the reception level of the pilot channel. Signals from a plurality of base stations can be despread concurrently to measure the strength of a pilot signal received from each base

station, or they can alternatively be immediately stored in a memory prior to despreading. The structure of a receiver having such a configuration according to the present invention will be described later in detail with reference to FIG. 12.

Tp may be predetermined as a constant value, or may vary for each base station to obtain the best effect by taking the geographical environment of the base station and its cell size into account in the embodiments depicted in FIGs. 5A and 5B. In addition, pilot power levels PWR(A), PWR(B), and PWR(C) which define the measured power level of the pilot channels may be set to an identical value when the terminal is located in a handoff region. The terminal compares the strengths of pilot channels received from base stations when it implements a handoff, and if the pilot powers are different, the terminal has difficulty in comparing relative power rates of the base stations.

FIG. 6 illustrates the effects of increasing the power of a pilot signal according to the embodiments of the present invention. In FIG. 6A, it is assumed that there exist two base stations and a terminal despreads input signals during the same integration time period, to show an area where two base station signals are acquired in the prior art. Also shown in FIG. 6A is an extended area for acquiring a base station signal and a base station signal acquirable area extended by increasing the power of a pilot signal according to the present invention. Here, a chip rate is 3.6864Mcps and a pilot Ec/Ior is usually sent at -12dB. Ior is the power spectral density of a signal sent from a base station, and the integration time period during spreading is 2048 chips. In addition, Tp occupies 2048 chips and the terminal stores the input signals in a memory prior to despreading. It is assumed that the channels exist in a stationary propagation environment without multipath, wave strength is proportional to a 3.5 square of distance, and the terminal can acquire a base station signal only if a pilot Et/Io is 11dB or higher after despreading. Et represents the

energy of a despread signal and Lo represents the power spectral density of an input signal.

Referring to FIG. 6, let the distance between base stations be L, the location of a base station A be 0, and the location of a base station B be L. Then, signals from the base stations A and B can be acquired as long as the terminal is located between 0.35L and 0.65L from the base station A in accordance with the prior art, whereas the two signal acquiring area is greatly increased to 0.19L to 0.81L by assigning the total base station power to a pilot channel for a predetermined period Tp in the present invention. The same effect can be achieved with a plurality of base stations. This method can be applied, for example, to location estimation on a forward link.

There is another advantage with instantaneously increasing the ratio of the pilot signal power to the overall transmission power by increasing the pilot signal power. The pilot signal is used for initial acquisition, channel estimation, and set management for handoff. As the bandwidth increases, a window size for finger assignment also increases. Hence, it is difficult to reduce the pilot power to or below a predetermined value. Higher system capacity can be obtained as compared with the prior art by lowering the power of the pilot signal in ordinary times and increasing the pilot power only for a specified time period, as described in the present embodiment.

If the pilot signal power is dropped to or below a predetermined value, a receiver should integrate an input signal for a longer time to measure the level of an input pilot signal on a pilot channel, resulting in degradation of measurement performance for finger assignment and set management. The performance degradation can be reduced by use of a terminal with more complex hardware and

power consumption. Yet, the present invention guarantees a terminal performance as good as or better than a terminal performance based on IS-95 to be designed with simple hardware and low power consumption by instantaneously increasing the pilot signal power.

A multipath resolution capability of a received signal increases with a wider bandwidth, which implies that reception energy for each path is decreased. A rake receiver exerts improved performance as it demodulates signals from more paths. However, to acquire multiple paths at or below a predetermined level and assign them to a finger, correlation values should be produced for a long time. This may increase power consumption and complexity of the receiver. The present invention allows an efficient finger assignment by detecting a multipath signal at a low level through calculation of correlation values for a relatively short time period.

Efforts have been expended toward storing a received signal in a storing means prior to processing in the CDMA communication system. This method has been studied to determine whether it is effective in measuring reception level for a hard handoff between frequencies. By use of the pilot power increasing method of the present invention, the number of samples of an input signal to be stored in the storing means is markedly reduced, terminal hardware is simplified, the time required for calculating correlation values is reduced, and thus power is saved. That is, if the temporary increase of pilot signal power and a search for hard handoff between frequencies happen concurrently and a signal received for the time period of the temporary pilot power increase is stored, the number of input samples to be stored in the terminal and a search time through despreading are remarkably reduced. Besides the search for a hard handoff between frequencies, storing an input signal prior to despreading and processing a pilot signal can reduce complexity of a needed storage and signal processing amount.

While various effects of increasing pilot signal power for a specified time period have been described referring to FIGs. 4A and 4B, the effects are not limited to the embodiments depicted in the drawings, but commonly applied to all structures suggested in the present invention.

FIG. 7 illustrates distribution of the transmission power of a base station by dividing the power of a pilot signal using different spreading codes. The increase of the pilot signal strength for a short time is likely to influence receiving blocks including a channel estimator. If there exists a terminal in the same area which is not informed of the change of the pilot signal power for a short time or a terminal which has not been synchronized yet, a change of a pilot channel may give rise to problems like connection to a wrong base station.

In accordance with an embodiment illustrated in FIG. 7A, the power of a pilot channel is increased, the pilot signal with increased power is spread by different spreading codes and the resulting different code channels are transmitted, for a time period Tp. The spreading codes are exemplarily given as W'0, W'1, ..., W'n in FIG. 7A. This pilot channel is applicable to the structures previously described with reference to FIGs. 4A to 5B. Power for use in a common pilot channel is equally assigned to Tp and the other normal period and the pilot signal power increased for Tp is spread by a plurality of spreading codes different from a spreading code for the common pilot signal prior to transmission, not to affect other existing receivers. The common pilot signal refers to a pilot signal used in a normal period other than Tp.

In this case, the pilot signal P(t) is

$$P(t) = GO*CO(t)+G1*C1(t)+ \ldots +Gn*Cn(t) \qquad (2)$$

where GO to Gn are gains of code channels and CO(t) to Cn(t) are spreading codes for pilot channels.

In Eq.2, it is assumed that a pilot channel is transmitted on different (n+1) code channels. The gains GO to Gn can be expressed as complex numbers and the spreading codes CO(t) to Cn(t) can be orthogonal codes. It is also possible that the spreading codes CO(t) to Cn(t) are not orthogonal to each other.

FIG. 8 is a block diagram of a transmitting device in a base station, for separately transmitting a pilot channel signal with a plurality of spreading codes. The pilot channel signal is spread by a plurality of orthogonal codes, multiplied by different gains, and spread by the same spreading code, for transmission. The base station transmitting device of FIG. 8 shows other channel transmitters as well as a pilot channel transmitter. The transmitting device includes the pilot channel transmitter for sending the pilot channel by n different Walsh codes, a synch channel transmitter, a paging channel transmitter, and M traffic channel transmitters. A time controller 81 controls the gain of each channel at a specified time.

In the embodiments illustrated by FIGs. 4A and 4B where the pilot signal power is instantaneously increased, the time controller 81 controls the gain of each channel for a time period Tp so that the pilot signal is transmitted at a higher power level than usual. The power of other channels are changed within a range determined by the overall transmission power of the base station for a time period Tp. It is to be appreciated that while the base station transmitting device for increasing the pilot channel power for a specified time has been described in connection with FIG. 8, the transmitting device is applicable to structures which will be later described by appropriately controlling the gain of each channel.

In operation, a pilot signal being all 1s is spread by the orthogonal codes W'0, W'1, ..., W'n in respective multipliers 80-0, 80-1, ..., 80-n, and then multiplied by different gains G0, G1, ..., Gn in respective gain controllers 82-0, 82-1, ..., 82-n whose operating times are controlled by the time controller 81. The outputs of the gain controllers 82-0, 82-1, ..., 82-n are added in adders 84, 86, and 68 and multiplied by the same PN (Pseudo Noise) spreading code, for transmission. That is, the pilot channel signal is spread by a plurality of orthogonal codes, multiplied by different gains, and spread by the same spreading code, prior to transmission.

In FIG. 8, a synch channel data symbol signal is spread by an orthogonal code Ws in a multiplier 50 and multiplied by a gain Gs in a gain controller 52 whose operating time is controlled by the time controller 81. Then, the output of the gain controller 52 is added in an adder 66 and multiplied by the same PN spreading code in the multiplier 88, for transmission.

A paging channel data symbol signal is spread by an orthogonal code Wp in a multiplier 54 and multiplied by a gain Gp in a gain controller 56 whose operating time is controlled by the time controller 81. Then, the output of the gain controller 56 is added in an adder 64 and multiplied by the same PN spreading code in the multiplier 88, for transmission.

A traffic channel 1 data symbol signal is spread by an orthogonal code W_{T1} in a multiplier 58-1 and multiplied by a gain GT1 in a gain controller 60-1 whose operating time is controlled by the time controller 81. Then, the output of the gain controller 60-1 is added in an adder 62 and multiplied by the same PN spreading code in the multiplier 88, for transmission. In this manner, a traffic channel M data symbol signal is spread by an orthogonal code W_{TM} in a multiplier 58-M and multiplied by a gain G_{TM} in a gain controller 60-M whose operating time is

controlled by the time controller 81. Then, the output of the gain controller 60-M is added in the adder 62 and multiplied by the same PN spreading code in the multiplier 88, for transmission.

Spreading a pilot signal by different spreading codes more than usual for a specified time period, for transmission, and a transmitting device for implementing the operation have been described with reference to FIGs. 7 and 8. This scheme is commonly applicable to all structures according to the present invention as well as the embodiments of FIGs. 4A and 4B.

The challenging issue in acquiring signals from a plurality of base stations on a forward link by a terminal is that a terminal near to a base station cannot detect signals from other base station because the terminal receives a very strong signal from the nearby base station. That is, the signal of the nearby base station interferes with a signal from a remotely located base station, making it impossible for the terminal to detect the signal of the remote base station. To overcome this problem, the present invention decreases the overall transmission power of the nearby base station for a predetermined time Td.

FIGs. 9A and 9B illustrate embodiments in which the overall transmission power of a base station is lowered for Td. A corresponding base station sends some channel signals at a lower power level than usual or does not send them, for Td. Td is preset by mutual agreement between the base station and a terminal. Td can be periodic or determined by the base station.

FIG. 9A illustrates the embodiment where the base station sends a base station signal at a lower than normal power level for a time period Td. Here, the decrement is $\Delta P3$, and the transmission power of a pilot channel signal may be

changed. In FIG. 9A, the decrement of the pilot signal power is ΔP4. Assuming that the overall transmission power density Ior and energy per chip of a pilot channel is Ec,

$$\frac{pilot\ Ec + \Delta P_4}{Ior\ - \Delta P_3} > \frac{\text{pilot Ec}}{\text{Ior}} \tag{3}$$

Though ΔP4 is a positive number in the embodiment of FIG. 9A, it can be a negative numeral as long as it satisfies Eq.3. ΔP4 can be zero to minimize an influence on other block in a receiver.

It is noted from Eq.3 that the ratio of the pilot signal power to the overall transmission power of the base station is temporarily higher than usual for a time period Td. In the embodiment of FIG. 9A, the overall transmission power of the base station is reduced and the pilot signal power is changed within a range satisfying Eq.3, so that the ratio of the pilot signal power to the overall transmission power of the base station is temporarily higher than usual. The embodiments of FIGs. 4A and 4B aim at controlling the ratio of the pilot channel power to the overall transmission power by increasing the pilot channel power, while the embodiment of FIG. 9A focuses on controlling the ratio of the pilot channel power to the overall transmission power by lowering the overall transmission power. As shown in FIG. 9A, the increase of the pilot channel power and the decrease of the overall transmission power can occur concurrently. Or the base station can send only the pilot channel for Td.

For a time period Td the base station may send no signals, that is, it does not send the pilot signal. FIG. 9B illustrates this scheme. That is, signals are sent at ordinary times but no signals including a pilot signal are sent for Td.

If there are a plurality of base stations in the vicinity of a terminal, Td is implemented by synchronization among the base stations. This is illustrated in FIGs. 10A, 10B, and 10C. It is assumed here that each base station is synchronized to a GPS (Global Positioning System). Td can be periodic or determined by a base station.

FIGs. 10A, 10B, and 10C illustrate the overall transmission power of a base station. In the embodiments depicted in FIGs. 10A and 10B, the pilot signal power satisfies Eq.3. In addition, the pilot signal power of the plurality of base stations can be set to be identical in order to facilitate comparison between reception levels of the pilot signals from the base stations. The embodiments of FIGs. 10A and 10B are based on the assumption that the pilot signal power is not changed for a time period Td.

Referring to FIG. 10A, the plurality of base stations are synchronized and their overall transmission power is lowered at the same time. The pilot channel is continuously sent for Td, and the pilot signal power can be changed within a range satisfying Eq.3. Here, the pilot channel power of each base station can be set to a constant level. The transmission powers of base stations A, B, and C are lower than usual by $\Delta P3(A)$, $\Delta P3(B)$, and $\Delta P3(C)$, respectively.

Time periods Td(A), Td(B), and Td(C) when the base stations lower their overall transmission power can be changed depending on their surroundings and cell sizes. The effect of the embodiment shown in FIG. 10A is that the ratio of the pilot channel power to the overall transmission power of a base station is instantaneously increased by lowering the overall transmission power of the base station. That is, the ratio of the pilot channel power to the overall transmission power of a base station is instantaneously increased by increasing the pilot channel

power in FIGs. 4A and 4B, while by lowering the overall transmission power of the base station in FIG. 10A. In the embodiment of FIG. 10A, the terminal can easily detect signals from other base stations since pilot signals sent from the base stations are relatively strong.

FIG. 10B illustrates another embodiment of the method of lowering the overall transmission power of a base station for a specified time period. It is assumed that each base station is synchronized to a GPS time. Unlike the previous embodiment, all base stations do not decrease their overall transmission power. That is, only one base station lowers its overall transmission power. Yet, a plurality of base stations can reduce their overall transmission power and the other base stations perform normal operations. In this embodiment, there are three base stations A, B, and C, the time periods Td(A), Td(B), and Td(C) when the base stations A, B, and C reduce their overall transmission power are different, and the power drop occurs alternately in the base stations A, B, and C while the other base stations send signals at their normal overall transmission power levels.

FIG. 10C is a further embodiment of the method of lowering the overall transmission power of a base station for a specified time period in an area with a plurality of base stations. Referring to FIG. 10C, the overall transmission power of a base station is decreased to zero (0) as shown in FIG. 9B, and the base station sends no signals including a pilot channel signal for a time period TD when the base station lowers the overall transmission power. Therefore, a terminal closer to the base station sending no signals can detects signals from other base stations.

Let all the base stations be grouped into a set S and the set S be divided into a plurality of subsets S1, S2, ..., SM. Then, base stations within a particular subset reduce their overall transmission power, possibly to zero, for a specified time

period, and the other base stations maintain their usual transmission power levels. If the overall transmission power levels of the corresponding base stations are not reduced to zero, their pilot channel signal power can be changed within a range satisfying Eq.3 for Td. Here, M is the number of the subsets. The subsets S1, S2, ..., SM can be designed such that there are no intersections between the subsets or where each subset has an intersection with another subset.

As described above, the present invention enables a terminal to easily acquire signals from a plurality of base stations by changing the power of a pilot signal sent from a particular base station or by changing the overall transmission power of the base station for a predetermined time Tp or Td and thus increasing the ratio of the pilot channel power to the overall transmission power from a normal value. Alternatively, a terminal near to a base station can easily acquire signals from other base stations by temporarily stopping transmission of signals from the nearby base station. Increasing the pilot signal power and decreasing the overall transmission power in combination lead to more benefits. The combination will be described later in detail with reference to FIGs. 11A and 11B.

FIG. 11A illustrates an embodiment of a combined scheme of increasing pilot signal power and decreasing overall transmission power. It is assumed that the plurality of base stations A, B, and C are synchronized to one another with use of a GPS, for example. Referring to FIG. 11A, some base stations reduce their overall transmission power and the other base stations increase their pilot signal power. Three base stations are shown, but the number of the base stations is not limited. The three base stations send no forward signals for Td. The time periods Tp(A), Tp(B), and Tp(C) when the base stations A, B, and C increase their pilot signal power can be set to different values. The time periods Td(A), Td(B), and Td(C) when they reduce their overall transmission power can also be different While the

overall transmission power of the base stations are not changed for Tp in this embodiment, it can be increased as shown in FIG. 4A. Tp and Td are periodic or determined by the base stations.

Pilot signals can be increased to an identical level for the base stations which do not reduce their overall transmission power. In FIG. 11A, when the base station A reduces its overall transmission power, the pilot signal power level PWR(B) of the base station B is made to be equal to that PWR(C) of the base station C, so as to allow a terminal to accurately measure the relative power level of an input signal. If the base stations A, B, and C always increase their pilot signal power to a predetermined level, that is, PWR(A) = PWR(B) = PWR(C) = K (the predetermined level), the terminal can accurately measure the power levels of pilot signals received on pilot channels from the base stations A, B, and C.

While the pilot signal power of each base station is part of the overall transmission power of the base station for Tp in the embodiment shown in FIG. 11A, the pilot signal power can be increased to the overall transmission power level.

FIG. 11B illustrates another embodiment of a combined scheme of increasing pilot signal power and decreasing overall transmission power. In FIG. 11B, the base stations A, B, and C transmit some channels without stopping signal transmission for Td(A), Td(B), and Td(C). While only the pilot channel is transmitted for Td(A), Td(B), and Td(C). In this embodiment, other channels can also be transmitted for the time periods Td(a), Td(B) and Td(C). In addition, the pilot signal power can be changed from its usual level for Td(A), Td(B), and Td(C). That is, the scheme of FIG. 9A is applicable for Td, and the scheme of FIGs. 4A and 4B for Tp. The time periods Tp(A), Tp(B), and Tp(C) when the base stations A, B, and C increase their pilot signal power can be set to different values. The

time periods Td(A), Td(B), and Td(C) associated with the reduction of overall transmission power can also be different.

As described above, the present invention enables a terminal to easily acquire signals from a plurality of base stations by changing the power of a pilot signal sent from a base station or the overall transmission power of the base station for the predetermined time Tp or Td, or by combining the two schemes, and thus increasing the ratio of the pilot chip energy Ec of a received pilot channel to a mobile reception power density Io for a specified time.

In various schemes according to the embodiments of the present invention, a terminal detects signals from a plurality of base stations by despreading signals received for Tp or Td and measures the levels, propagation delays, or relative propagation delays in a multipath, of the received signals. Which parameter to measure in the terminal vary depending on an intended purpose. If the terminal aims at measuring the distance between the terminal and a base station to thereby estimate its location, the necessary principal parameter is propagation delay. If the purpose of the terminal is finger assignment or handoff, the principal parameters to be measured are propagation delay in a multipath and signal level.

For example, for the purpose of location estimation, a terminal measures the distances between the base stations and the terminal using propagation delays among measured parameters and sends information about the distances to the base station in communication with the terminal. Therefore, the location of the terminal with respect to the base station in communication can be determined from the distance information. For finger assignment or set management for a handoff, the terminal will perform a set management for adjacent base stations using propagation delays and signal levels among the measured parameters.

A widely used serial searcher can be used in a receiver of the terminal in despreading and searching the signals. However, use of the serial searcher has the problem that Tp or Td may be set to be long. To reduce Tp or Td, the searcher of the receiver is configured as follows to perform despreading and search.

(1) A matched filter is used for the searcher. The matched filter can rapidly calculate a correlation value between a received signal and a partially generated spreading code. Despite the advantage of the rapid production of a correlation value, the matched filter increases complexity of receiver structure and power consumption.

The matched filter is difficult to achieve due to the limitations. In particular, if the power of a pilot channel is low, an integration period is long when calculating the correlation value between the received signal and the partially generated spreading code. Such a matched filter causes a great problem when it is used in a terminal. Yet, possible concurrence between a matched filter operating time and a time when the ratio of the pilot channel power to the overall base station power is temporarily changed may remarkably reduce the integration time needed to obtain the correlation value. As shown in FIG. 5A, a plurality of base stations sequentially change the ratios of pilot channel power to overall transmission power and the matched filter of the terminal can despread a signal with the spreading code of the base station which temporarily increases the ratio of the pilot channel power to the overall transmission power. It is impossible to calculate a correlation value between a received signal and a spreading code by use of the matched filter even in the structure of FIG. 5B. In this case, a despreading can be performed with a spreading code of a base station, or an input signal is stored in a memory and then despreading is sequentially performed.

(2) A received signal around Tp or Td is stored in a memory of a receiver and then a correlation value between this signal and a partially generated spreading code is calculated. This scheme requires the memory for storing the received signal but simplifies despreading and reduces power consumption. Here, the searcher is assumed to be a serial searcher.

In an embodiment of the present invention, a searcher is configured according to the second scheme. The structure of the searcher according to the embodiment of the present invention is illustrated in FIG. 12.

Referring to FIG. 12, the searcher according to the embodiment of the present invention is comprised of a despreader 100, a spreading code generator 102, a memory 104 for storing an input signal, an energy calculator 106, and a controller 108. The memory 104 stores an input signal around Tp or Td under the control of the controller 108. The controller 108 applies a control signal S1 (read/write) commanding the input signal around Tp or Td to be stored in the memory 104, and a control signal S2 (address) indicating at what position in the memory 104 to store the input signal. Upon input of a signal, the controller 108 increases the address of the control signal S2 and stores the input signal in the memory 104. Then, the controller 108 causes the memory 104 to output the stored signal to the despreader 100. Here, the controller 108 controls the memory 104 to output the stored signal by means of the control signal S1 and designates a storing position by means of the control signal S2. The spreading code generator 102 locally generates the same spreading code as a transmitter of a base station and applies it to the despreader 100. The despreader 100 multiplies the input signal received from the memory 104 by the spreading code and integrates the resulting value for a predetermined time. The spreading code generator 102 locally generates a spreading code (i.e., a Walsh code). The energy calculator 106 calculates the energy of the despread signal. To

do so, the sum of the squares of despread values with respect to I and Q axes, that is, I^2+Q^2 is obtained. This is Ec/Io of a received pilot channel. Here, Ec represents energy per chip of an input signal and Io represents the power spectral density of an entire received CDMA signal.

FIG. 13 is a block diagram of the despreader 100 shown in FIG. 12. All signals in FIG. 13 are expressed as complex numbers. In an embodiment of FIG. 13, a pilot channel is spread with a spreading code like the forward link shown in FIG. 4.

Referring to FIG. 13, a multiplier 110 multiplies an input signal by a PN spreading code for despreading. A multiplier 112 multiplies the despread signal received from the multiplier 110 by a corresponding orthogonal code, for orthogonal demodulation. An accumulator 114 accumulates the output of the multiplier 112 in symbol units.

FIG. 14 is a block diagram of a despreader for despreading a pilot signal which was spread with a plurality of spreading codes as shown in FIGs. 7 and 8, in a receiver according to a first embodiment of the present invention. The first embodiment of FIG. 14 is a despreader employed for the case where a pilot channel is spread with the plurality of orthogonal codes W'0, W'1, ..., W'n and then with a single common PN spreading code in a base station. Here, all signals take the form of complex numbers.

Referring to FIG. 14, a multiplier 210 multiplies an input signal by a PN spreading code, for despreading. Multipliers 220 to 22N receive a despreading signal from the multiplier 210 and multiply the despreading signal by corresponding orthogonal codes W0' to WN', for orthogonal demodulation. Accumulators 230 to

23N accumulate the outputs of the multipliers 220 to 22N. An accumulation period can be different for each accumulator to accumulate a channel which is transmitted at all times like a pilot signal spread by W'0 for a longer time. In this case, a gain multiplier in the receiver should be changed in consideration of the accumulation time. In the embodiment of the present invention, it is assumed that an accumulation period for an accumulator for receiving each orthogonal code channel is constant. Multipliers 240 to 24N multiply the outputs of the corresponding accumulators 230 to 23N by complex conjugates G0* to GN* of corresponding complex gains G0 to GN, for compensating the phases of the complex gains G0 to GN. An adder 250 adds the outputs of the multipliers 240 to 24N. A squarer 260 squares the output of the adder 250 and converts the resulting value to an energy value. A multiplier 270 multiplies the output of the squarer 260 by the sum of the squares of the gains of channels to normalize the output of the squarer 260.

As shown in FIG. 14, an input signal is multiplied by a PN spreading code, for despreading in the multiplier 210. The despread signal is multiplied by corresponding orthogonal codes in the multipliers 220 to 22N. Signals output from the multipliers 220 to 22N are accumulated in symbol units in the accumulators 230 to 23N. Then, the multipliers 240 to 24N multiply the outputs of the accumulators 230 to 23N by corresponding gains G0* to GN* to thereby compensate for phase components of the complex gains multiplied by the orthogonal channels. The adder 250 adds the phase-compensated signals and the squarer 260 converts the sum received from the adder 250 to an energy value. Then, the multiplier 270 multiplies the output gain of the adder 250 by

$$\frac{1}{\sum_{2} |Gi|^2}$$

to normalize the output gain of the adder 250. That is, a value multiplied for the gain compensation is 1/the sum of the squares of the complex gains Gi (i= 0, 1, 2,

..., n) of the orthogonal codes. Here, the multiplier 270 is used to obtain a good gain compensation.

The despreader shown in FIG. 14 depsreads an input signal, accumulates the despread signal in symbol units, and then obtains the energy of the accumulated signals.

In FIG. 14, (n+1) despreaders despread an input signal in parallel. However, the receiver can despread only a part of (n+1) orthogonal codes received from a base station. That is, the receiver can despread some or all of the orthogonal codes assigned to a pilot channel in FIG. 7 though there is a light performance degradation.

FIG. 15 illustrates a despreader in a terminal receiver according to a second embodiment of the present invention, which is employed in the case where a transmitter in a base station spreads a pilot channel by a plurality of orthogonal codes. In the despreading method according to the second embodiment of the present invention, input signals having the same spreading codes are grouped to reduce power consumption, as compared to the structure of FIG. 14. While two orthogonal codes are used here, this structure can be extended to a plurality of orthogonal codes. All signals in FIG. 15 take the form of complex numbers.

Referring to FIG. 15, a multiplier 310 multiplies an input signal by a PN spreading code, for despreading. A multiplier 320 multiplies the output of the multiplier 310 by an orthogonal code and generates an orthogonally demodulated output. Here, the orthogonal code applied to the multiplier 320 is assumed to be W'0. A switch controller 380 receives the orthogonal codes W0' and W1' and searches the two orthogonal codes in chip units. If W0'(i)=W1'(i), the switch

controller 380 generates a control signal for selecting a first path, and If $W0'(i) \neq W1'(i)$, the switch controller 380 generates a control signal for selecting a second path. The orthogonal code $W0'(i)$ is the ith chip of the orthogonal code $W0'$ and the orthogonal code $W1'(i)$ is the ith chip of the orthogonal code $W1'$. A switch 381 has an input terminal connected to the multiplier 320, a first output terminal connected to a first path A, and a second output terminal to a second path B. The switch 381 switches the output of the multiplier 320 to the first path A or the second path B according to the output of the switch controller 380.

An accumulator 330 accumulates signals received from the first path A. A multiplier 340 multiplies the output of the accumulator 330 by a complex gain $(G0+G1)^*$ and thus compensates for the phase gain of a signal output to the first path A. Signals switched to the first path A have orthogonal codes comprised of chips of the same sign. An accumulator 331 accumulates signals received from the second path B. A multiplier 341 multiplies the output of the accumulator 331 by a complex gain $(G0-G1)^*$ and thus compensates for the phase gain of a signal output to the second path B. Signals switched to the second path B have orthogonal codes comprised of chips of different signs. An adder 350 adds the outputs of the multipliers 340 and 341. A square 360 squares the output of the adder 350 to be converted to an energy value. A multiplier 370 multiplies the output of the squarer 360 by

$$\frac{1}{2\sum_{2}|Gi|^2}$$

to normalize the output of the squarer 360.

The operation of the structure shown in FIG. 15 will be described from a theoretical perspective. Here, the length of the orthogonal codes W0 and W1 used in FIG. 15 is 8 chips (i=8). It is assumed that the pattern of $W0'$ is +1, +1, +1, +1,

−1, −1, −1, −1, and the pattern of W1′ is +1, +1, −1, −1, +1, +1, −1, −1. Then, the orthogonal codes W0 and W1 are

(Table 1)

orthogonal code	chip number
	i1 i2 i3 i4 i5 i6 i7 i8
W0′	+1 +1 +1 +1 −1 −1 −1 −1
W1′	+1 +1 −1 −1 +1 +1 −1 −1

Assuming that an input signal to the despreader is $r_1, r_2, r_3, r_4, r_5, r_6, r_7, r_8$ and gains multiplied by the orthogonal codes are G0 and G1, the input signal spread by W0′ is

$$Y0 = G_0^* (r_1 + r_2 + r_3 + r_4 - r_5 - r_6 - r_7 - r_8)$$
$$Y1 = G_1^* (r_1 + r_2 - r_3 - r_4 + r_5 + r_6 - r_7 - r_8)$$

Here, a final output of the despreader is Y0+Y1.

The orthogonal codes W0′ and W1′ have the same chip components in the first, second, seventh, and eighth positions, and different chip components in the third, fourth, fifth, and sixth positions. The components of Y0+Y1 are classified depending on whether chip components of the orthogonal code W0′ are the same as or different from those of the orthogonal code W1′. If these are called X0 and X1,

$$X0 = (G_0^* + G_1^*) (r_1 + r_2 - r_7 - r_8)$$
$$X1 = (G_0^* - G_1^*) (r_3 + r_4 - r_5 - r_6)$$

Here, X0+X1=Y0+Y1. It is noted from the above formula that classification of inputs according to combinations of chip components of each orthogonal code reduces the number of additions performed during despreading. This is effective not with a shorter orthogonal code but with a longer orthogonal code.

The above scheme is implemented in hardware in FIG. 15. In FIG. 15, an input signal is multiplied by a PN spreading code in the multiplier 310 and by the orthogonal code W0′. Then, the switch controller 380 generates a switch control signal by determining whether chip components of the two orthogonal codes are the same or different. The switch 381 selectively outputs the output of the multiplier 320 to the two accumulators 330 and 331 based on the switch control signal. Here, a signal multiplied by the PN spreading code and then the orthogonal code W0′ is applied to the input of the accumulator 330 in the first path A if the chip components of the two orthogonal codes W0′ and W1′ are the same, and to the input of the accumulator 331 in the second path if the chip components are different. Signals separated by the switch 381 are added in the accumulators 330 and 331 in symbol units. Then, the multiplier 340 multiplies the output of the accumulator 330 by $G_0^* + G_1^*$, and the adder 350 adds the outputs of the multipliers 340 and 341. The output of the adder 350 is squared in the squarer 360 and thus converted to an energy value. The multiplier 370 multiplies the output of the squarer 360 by a gain

$$\frac{1}{2\sum_{2}|Gi|^2}$$

for normalizing the resulting values from multiplying gains in the multipliers 340 and 341.

If a pilot signal is spread by a plurality of spreading codes for transmission in the above receiver, a terminal should know the power ratio or gain value assigned

to each orthogonal code. This can be preset in standards or a base station can notify the terminal by a system parameter. Or the receiver can measure it in a simple algorithm. This can be estimated by obtaining the energy ratio of a despread signal for each orthogonal code.

FIG. 16 illustrates the structure of a despreader in a receiver according to a third embodiment of the present invention in the case where a pilot signal is spread by different spreading codes as shown in FIGs. 7 and 8. The third embodiment of FIG. 16 is for the case where a pilot channel is spread by a plurality of orthogonal codes W0′, W1′, ..., Wn′ and then by a common PN spreading code. All signals in FIG. 16 take the form of complex numbers.

Referring to FIG. 16, a multiplier 210 multiplies a received signal by a PN spreading code, for despreading. Multipliers 220 to 22N multiplies a despread signal received from the multiplier 210 by corresponding orthogonal codes W0′ to WN′, for orthogonal demodulation. Accumulators 230 to 23N accumulate the outputs of the multipliers 220 to 22N in symbol units. Squarers 240 to 24N square the outputs of the accumulators 230 to 23N to be changed to an energy value. An adder 250 adds the outputs of the squarers 240 to 24N.

In the despreader of FIG. 16, a received signal is despread and accumulated in symbol units, and then an energy value is obtained. The drawing illustrates the despreader and the energy calculator of FIG. 12 in detail. The despreader and the energy calculator of FIG. 16 calculates the energy of each channel and then adds the energies as compared to other despreaders. While despread values for the channels are added coherently in FIGs. 14 and 15, the energy of each channel is calculated and energies are added in FIG. 16. In this case, performance is slightly degraded relative to the despreader of FIGs. 14 and 15, but even if the gain of each channel

is unknown, the power ratio of a plot channel received from a base station can be obtained.

FIG. 17 illustrates a despreader in a terminal receiver according to a fourth embodiment of the present invention. The embodiment of FIG. 17 is for the case a pilot channel of a base station is spread by (n+1) mutually orthogonal codes W0′, W1′, ..., Wn′ and then by a common PN spreading code. In FIG. 17, the despreader is comprised of a multiplier 120 for multiplying an input signal by a PN spreading code, (n+1) multipliers 122-0 to 122-n using (n+1) different orthogonal codes for despreading, (n+1) accumulators 124-0 to 124-n for accumulating different orthogonal channel signals for a specified time, (n+1) multipliers 126-0 to 126-n for compensating a phase multiplied by each orthogonal channel in a base station transmitter, and an adder 128 for adding the outputs of the multipliers 126-0 to 126-n. An input signal is multiplied by a PN spreading code in the multiplier 120 and then by different orthogonal codes W0′ to WN′ in the multipliers 122-0 to 122-n. The outputs of the multipliers 122-0 to 122-n are accumulated in the (n+1) accumulators 124-0 to 124-n for a predetermined time, for despreading, and then outputs to the corresponding multipliers 126-0 to 126-n. The multipliers 126-0 to 126-n act to compensate for phase component of a complex gain multiplied b each orthogonal channel in the transmitter. A value multiplied for phase compensation is a value resulting from dividing the complex conjugate of the complex gain Gi (i = 0, 1, 2, ..., n) by a corresponding signal strength ($Gi^*/|Gi|$). The adder 128 adds the output signals of the multipliers 126-0 to 126-n.

When a terminal searches for an adjacent frequency for a hard handoff between frequencies in IMT-2000 standards, the terminal temporarily stops receiving a signal with a frequency f1, shifts to an intended adjacent frequency f2, and stores an input signal of the frequency f2 in a memory. Then, the terminal

returns to the old frequency f1 and continues receiving the old signal. Here, the terminal needs a memory for storing the input with an adjacent frequency. If the time when the input of the adjacent frequency is stored in the memory is concurrent with Tp or Td, the required capacity of the memory for storing the input of the adjacent frequency can be reduced. Assuming that the influence of propagation delay is negligible and pilot signal power is −12dB relative to the overall transmission power of a base station, the effect of storing 4000 chips in a conventional structure is the same that of storing 256 or 512 chips for Tp. FIG. 18 illustrates an embodiment to search for adjacent frequencies for a hard handoff between frequencies.

In the embodiment of FIG. 18, each base station increases the pilot signal power for Tp. The same effects can be obtained from the structures of FIGs. 9A and 9B. It is assumed here that each base station is synchronized by a GPS. A plurality of base stations temporarily increase pilot channel power for Tp. A terminal stores a signal generated for Tp in a memory. The terminal receives a input signal with the frequency f1 at ordinary times. If the terminal needs to receive a signal with the adjacent frequency f2, the receiver temporarily stops receiving the signal with the frequency and shifts to the adjacent frequency f2 for a short time Tt1. If the signal with the frequency f2 is stable, the terminal stores the input signal with the frequency f2 in the memory for Ts. Ts is concurrent with Tp. Then, the terminal returns to the frequency f1. It is assumed that time required for shifting to the frequency f1 and stabilizing it is Tt2. If the frequency f1 is stabilized, the terminal continues receiving the signal with the frequency f1 and searches for the adjacent frequency f2 from the signal stored in the memory. In the embodiment of the present invention, the search for the adjacent frequency f2 starts after Tt2 but it can start after Ts when storage is completed.

In accordance with the embodiment of FIG. 18, Tp is concurrent with the time period for which the signal with an adjacent frequency is stored in the memory for search for the adjacent frequency. Therefore, the required capacity of the memory and power consumption can be reduced.

In the above embodiments, a base station sends a signal with an increased ratio of pilot signal power to the overall transmission power of the base station for a predetermined period, so that a terminal can easily acquire the signal. In other embodiments, signal acquisition in a terminal can be facilitated by increasing the ratio of the power of a specific data channel to the transmission power in a base station.

In these embodiments, the power of a specific data channel Chi is increased for a predetermined period for efficient search in a terminal. The terminal despreads the received signal at the higher power level for a specified time period, detects signals from a plurality of base stations, and measures the signal level, delay, or delay relative to other paths of a multipath signal received from each base station.

Here, "specific data channel" refers to a forward common channel used to send additional information in the following embodiments of the present invention, and the power of the data channel is increased for a predetermined time, which should be preset based on a mutual agreement between a base station and a terminal.

FIGs. 19A and 19B illustrate the structure of a forward link according to embodiments of the present invention. Here, a base station sends a specific data channel signal at an increased power level for a predetermined period Tpp so that

a terminal can acquire signals from a plurality of base stations. In the embodiments, it is assumed that the specific data channel is a forward common channel used to send additional information. This channel may be a channel for sending non-encoded or non-interleaved information at the increased power level for Tpp. Information to be transmitted in this case could be an instruction that system set-up information should be updated because of the change of system set-up. The signal on the data channel with an increased power for Tpp can be sent only for Tpp. That is, for a search operation in the terminal, the signal with high power exists only for Tpp.

Referring to FIG. 19A, the base station increases the power of the data channel signal for the predetermined time period. In this embodiment, the overall transmission power of the base station is not changed. That is, signals on other channels are sent at a decreased transmission power level or are not sent, and the rest of the available power is assigned to a channel on which to send data symbols at a high power level. For more efficient set management, the entire transmission power of the base station may be assigned to the symbols on the data channel for Tpp. If there is a pilot channel, the transmission power except for the pilot signal power can be assigned to the data channel symbols.

The power level of the data channel at normal time (except Tpp) can be set to 0. That is, the data channel of this invention can be transmitted for Tpp time interval. The power level increment at Tpp time interval can be proportional to the power level of specific forward common channel. For example, the power level increment at Tpp interval can be proportional to the power level of forward common pilot channel, if the pilot channel exists.

FIG. 19A shows a case where signals on the other channels except for the

data channel with an increased power for Tpp are sent with low power or not sent for the time period defined by Tpp. Also, Tpp is specified at the boundary between two data frames. This is intended to prevent performance degradation caused by transmission of other data channel signals at a lower power level than usual. In addition, Tpp is preferably located over two consecutive data frames, with Tpp/2 over each data frame, for uniform performance of the two data frames. The terminal which acquires synchronization should already know the value specified Tpp and its location with respect to the data frames.

Because Tpp is specified in the same way as Tp described referring to FIG. 4A, its detailed description will be omitted.

FIG. 19B shows another embodiment of increasing the power of a specific data channel signal for a time period Tpp. Here, data channel signals are sent for Tpp, the entire transmission power of the base station is increased by an amount ΔP22 for the duration of the transmission, Tpp. The data channel signal power is increased by ΔP11 for Tpp. Here, ΔP22 and ΔP11 may be equal or different. That is, this embodiment is characterized by the concurrent increase of the entire transmission power of the base station and the specific data channel signal power. As a result, the rates of the data channel signal power and the overall transmission power of the base station are temporarily increased from their ordinary levels. Assuming that a usual overall transmission power density of the base sation is Ior and energy per chip of the data channel signal is Ec,

$$\frac{\text{data channel Ec} + \Delta P_{11}}{\text{Ior} + \Delta P_{22}} > \frac{\text{data channel Ec}}{\text{Ior}} \qquad (4)$$

Equation 4 illustrates the fact that the ratio of the data channel signal power

to the overall transmission power of the base station is instantaneously higher than usual.

It should be noted that it is feasible for the power of the data channel to rise to the usual overall transmission power of the base station (i.e., usual overall transmission power +△P22). In this case, the base station transmits only the data channel signal and punctures the other channels.

The embodiment of FIG. 19B is the same as that of FIG. 19A in that Tpp is located at the data frame boundary, and the terminal should know the value of Tpp and its location. Tpp can be periodic or determined by the base station.

If there are a plurality of base stations around a terminal, the base stations are synchronized with respect to Tpp so that the base stations can increase the power of their respective signals on the specific data channels concurrently. It is further contemplated that the base stations can otherwise increase their powers of the signals on the specific data channels alternately. The time period Tpp when each base station increases its signal power for the specific data channel can be periodic or determined by the base station.

FIG. 19C shows a further embodiment of increasing the power of a specific data channel signal for the time period Tpp. Here, the signal on the specific data channel Chi is sent only for Tpp. Data symbols sent for Tpp may be non-encoded or non-interleaved ones. The overall transmission power of the base station is increased by △P22 for Tpp, and the data channel signal power is increased by PWR_S for Tpp. Here, △P22 and PWR_S may be equal or different. That is, this embodiment is characterized by the concurrent change of the entire transmission power of the base station and the specific data channel signal power. As a result,

the rates of the data channel signal power and the overall transmission power of the base station are temporarily increased from their ordinary levels. Thus, the ratio of the data channel signal power to the overall transmission power. It should be noted that it is feasible for the power of the data channel to rise to the usual overall transmission power of the base station (i.e., usual overall transmission power $+\Delta P22$). In this case, the base station transmits only the data channel signal and punctures the other channels.

The embodiment of FIG. 19C is the same as that of FIG. 19A in that Tpp is located at the data frame boundary, and the terminal should know the value of Tpp and its location. Tpp can be periodic or determined by the base station.

FIG. 19D shows a case where signals on the other channels except for the specific data channel with an increased power for Tpp and a pilot channel with a predetermined transmission power are sent with low power or not sent for the time period defined by Tpp. The power level of the data channel at normal time (except Tpp) can be set to 0. That is, the data channel of this invention can be transmitted for Tpp time interval.

If there are a plurality of base stations around a terminal, the base stations are synchronized with respect to Tpp so that the base stations can increase the power of their respective signals on the specific data channels concurrently. It is further contemplated that the base stations can otherwise increase their powers of the signals on the specific data channels alternately. The time period Tpp when each base station increases its signal power for the specific data channel can be periodic or determined by the base station.

FIGs. 20A and 20B illustrate operations of base stations with a plurality of

timings synchronized. In the drawings, only specific data channel signal power is shown. Here, the overall transmission power of a base station can be maintained at a usual level or increased by ΔP22 as shown in FIG. 19A. The significant thing is that the ratio of the specific data channel signal power to the overall transmission power of the base station is instantaneously higher than usual.

A detailed description of FIGs. 20A and 20B will be omitted since it is almost the same as that of FIGs. 5A and 5B. That is, if "pilot signal power" is replaced by "specific data channel signal power" and "Tp" by "Tpp", the description of FIGs. 5A and 5B can be used for FIGs. 20A and 20B.

Also, for a detailed description of the effects of increasing the power of the signal on the specific data channel, a description for FIG. 6 can be referred to.

FIG. 21 is a block diagram of a transmitting device in a base station, for transmitting a signal on a specific data channel Chi at an instantaneously increased power level. The transmitting device includes a transmitter for the specific data channel, a pilot channel transmitter, a synch channel transmitter, a paging channel transmitter, and M traffic channel transmitters.

Referring to FIG. 21, a time controller 181 controls the gain of each channel for a predetermined time period Tpp so that the specific data channel signal is transmitted at a higher power level than usual. The powers of the other channels are changed within a range determined by the overall transmission power of the base station for a time period Tpp. It is to be appreciated that while the base station transmitting device for increasing the specific data channel power for a specified time has been described in connection with FIG. 21, the transmitting device is applicable to structures which will be later described by appropriately controlling

the gain of each channel.

In operation, a pilot signal being all 1s is spread by an orthogonal code W0′ in a multiplier 180, and then multiplied by a gain G0 in a gain controller 182 whose operating time is controlled by the time controller 181. The output of the gain controller 182 is added to another channel signal in an adder 170 and multiplied by the same PN spreading code in a multiplier 188, for transmission.

The specific data channel signal for sending additional information is spread by an orthogonal code Wchi in a multiplier 184, and then multiplied by a gain Gch in a gain controller 186 whose operating time is controlled by the time controller 181. The output of the gain controller 186 is added to another channel signal in an adder 168 and multiplied by the same PN spreading code, for transmission. The signal on the specific data channel can be transmitted at a much higher transmission power level for Tpp, or sent only for Tpp. The specific data channel may be a forward common channel.

A synch channel data symbol signal is spread by an orthogonal code Ws in a multiplier 150 and multiplied by a gain Gs in a gain controller 152 whose operating time is controlled by the time controller 181. Then, the output of the gain controller 152 is added in an adder 166 and multiplied by the same PN spreading code in the multiplier 188, for transmission.

A paging channel data symbol signal is spread by an orthogonal code Wp in a multiplier 154 and multiplied by a gain Gp in a gain controller 156 whose operating time is controlled by the time controller 181. Then, the output of the gain controller 156 is added in an adder 164 and multiplied by the same PN spreading code in the multiplier 188, for transmission.

A traffic channel 1 data symbol signal is spread by an orthogonal code WT1 in a multiplier 158-1 and multiplied by a gain GT1 in a gain controller 160-1 whose operating time is controlled by the time controller 181. Then, the output of the gain controller 160-1 is added in an adder 162 and multiplied by the same PN spreading code in the multiplier 188, for transmission.

A traffic channel M data symbol signal is spread by an orthogonal code WTM in a multiplier 158-M and multiplied by a gain GTM in a gain controller 160-M whose operating time is controlled by the time controller 181. Then, the output of the gain controller 160-M is added in the adder 162 and multiplied by the same PN spreading code in the multiplier 188, for transmission.

A transmitting device for increasing the power of the specific data channel for a specified time period have been described with reference to FIG. 21. This scheme is commonly applicable to all structures according to the present invention as well as the embodiments of FIGs. 19A to 19D.

The challenging issue in acquiring signals from a plurality of base stations on a forward link by a terminal is that a terminal near to a base station cannot detect signals from other base station because the terminal receives a very strong signal from the nearby base station. That is, the signal of the nearby base station interferes with a signal from a remotely located base station, making it impossible for the terminal to detect the signal of the remote base station. To overcome this problem, the present invention decreases the overall transmission power of the nearby base station for a predetermined time Tdd and changes the power of a specific data channel, to thereby control the rates of the power of the specific data channel and the overall transmission power.

FIG. 22 illustrates an embodiment in which the overall transmission power of a base station is lowered for Tdd. A corresponding base station sends some channel signals at a lower power level than usual or does not send them, for Tdd. Tdd is preset by mutual agreement between the base station and a terminal. Tdd can be periodic or determined by the base station.

FIG. 22 illustrates the embodiment where the base station sends a base station signal at a lower than normal power level for a time period Tdd. Here, the decrement is $\Delta P33$, and the transmission power of a specific channel signal may be changed. In FIG. 22, the decrement of the power of the specific data channel signal is $\Delta P44$. Assuming that the overall transmission power density Ior and energy per chip of the specific data channel is Ec,

$$\frac{\text{data channel Ec} + \Delta P_{44}}{\text{Ior} - \Delta P_{33}} > \frac{\text{data channel Ec}}{\text{Ior}} \qquad (5)$$

It is noted from Eq.5 that the ratio of the power of the specific data channel signal to the overall transmission power of the base station is temporarily higher than usual for a time period Tdd. In the embodiment of FIG. 22, the overall transmission power of the base station is reduced and the power of the specific data channel signal is changed within a range satisfying Eq.5, so that the ratio of the power of the specific data channel signal to the overall transmission power of the base station is temporarily higher than usual. The embodiments of FIGs. 19A, 19B, and 19C aim at controlling the ratio of the power of the specific data channel signal to the overall transmission power by increasing the power of the specific data channel signal, while the embodiment of FIG. 22 focuses on controlling the ratio of the power of the specific data channel signal to the overall transmission power by lowering the overall transmission power. As shown in FIG. 22, the increase of

the power of the specific data channel signal and the decrease of the overall transmission power can occur concurrently. Or the base station can send only the specific data channel signal for Tdd. If a pilot channel signal is transmitted all the time, the rest transmission power of the base station except for the power of the pilot channel signal can be assigned to the specific data channel signal.

If there are a plurality of base stations in the vicinity of a terminal, Tdd is implemented by synchronization among the base stations. This is illustrated in FIGs. 23A and 23B. It is assumed here that each base station is synchronized to a GPS (Global Positioning System). Tdd can be periodic or determined by a base station.

FIGs. 23A and 23B illustrate the overall transmission power of a base station. In the embodiments depicted in FIGs. 23A and 23B, the specific data channel signal power satisfies Eq.3. In addition, the power of the specific data channel signals of the plurality of base stations can be set to predetermined ratios to their polit signal powers in order to facilitate comparison between reception levels of the pilot signals from the base stations. The embodiments of FIGs. 23A and 23B are based on the assumption that the power of the specific data channel signal is not changed for a time period Tdd.

A detailed description of FIGs. 23A and 23B will be omitted since it is almost the same as that of FIGs. 10A and 10B. That is, if "pilot signal power" is replaced by "specific data channel signal power" and "Td" by "Tdd", the description of FIGs. 10A and 10B is applicable to the embodiments depicted referring to FIGs. 23A and 23B.

As described above, the present invention enables a terminal to easily acquire

signals from a plurality of base stations by changing the power of a specific data channel signal sent from a particular base station or by changing the overall transmission power of the base station for a predetermined time Tpp or Tdd and thus increasing the ratio of the power of the specific data channel signal to the overall transmission power from a normal value. Alternatively, a terminal near to a base station can easily acquire signals from other base stations by temporarily stopping transmission of signals from the nearby base station. Increasing the specific data channel signal power and decreasing the overall transmission power in combination lead to more benefits. The combination will be described later in detail with reference to FIGs. 24A and 24B.

A detailed description of FIGs. 24A and 24B will be omitted since it is almost the same as that of FIGs. 11A and 11B. That is, if "pilot signal power" is replaced by "specific data channel signal power", "Tp" by "Tpp", and "Td" by "Tdd", the description of FIGs. 11A and 11B is applicable to the embodiments depicted referring to FIGs. 24A and 24B.

As described above, the present invention enables a terminal to easily acquire signals from a plurality of base stations by changing the power of a specific data channel signal sent from a base station or the overall transmission power of the base station for the predetermined time Tpp or Tdd, or by combining the two schemes, and thus increasing the ratio of the specific data channel chip energy Ec to a mobile reception power density Io for a specified time.

In various schemes according to the embodiments of the present invention, a terminal detects signals from a plurality of base stations by despreading signals received for Tpp or Tdd and measures the levels, propagation delays, or relative propagation delays in a multipath, of the received signals. Here, the terminal can

detect a signal from each base station by depsreading a signal on a specific data channel. If a pilot signal is sent concurrently with the specific data channel signal, the base station signal can be detected by combining the signal levels of the pilot channel and the specific data channel. A réceiver in embodiments of the present invention is so configured as to detect a signal of each base station by despreading the specific data channel signal. Which parameter to measure in the terminal vary depending on an intended purpose. If the terminal aims at measuring the distance between the terminal and a base station to thereby estimate its location, the necessary principal parameter is propagation delay. If the purpose of the terminal is finger assignment or handoff, the principal parameters to be measured are propagation delay in a multipath and signal level. For example, for the purpose of location estimation, a terminal measures the distances between the base stations and the terminal using propagation delays among measured parameters and sends information about the distances to the base station in communication with the terminal. Therefore, the location of the terminal with respect to the base station in communication can be determined from the distance information. For finger assignment or set management for a handoff, the terminal will perform a set management for adjacent base stations using propagation delays and signal levels among the measured parameters.

The receiver according to the above embodiments of the present invention is the same in configuration and operation as that disclosed in FIGs. 12 and 13. Therefore, its detailed description will be omitted here.

When a terminal searches for an adjacent frequency for a hard handoff between frequencies in IMT-2000 standards, the terminal temporarily stops receiving a signal with a frequency f1, shifts to an intended adjacent frequency f2, and stores an input signal of the frequency f2 in a memory. Then, the terminal

returns to the old frequency f1 and continues receiving the old signal. Here, the terminal needs a memory for storing the input with an adjacent frequency. If the time when the input of the adjacent frequency is stored in the memory is concurrent with Tpp or Tdd, the required capacity of the memory for storing the input of the adjacent frequency can be reduced. Assuming that the influence of propagation delay is negligible and pilot signal power is −12dB relative to the overall transmission power of a base station, the effect of storing 4000 chips in a conventional structure is the same that of storing 256 or 512 chips for Tp. FIG. 25 illustrates an embodiment to search for adjacent frequencies for a hard handoff between frequencies.

In the embodiment of FIG. 25, each base station increases the power of a specific data channel signal for Tpp. The same effects can be obtained from the structure of FIG. 22. It is assumed here that each base station is synchronized by a GPS. A plurality of base stations temporarily increase the power of the specific data channel signal for Tpp. A terminal stores a signal generated for Tpp in a memory. The terminal receives an input signal with the frequency f1 at ordinary times. If the terminal needs to receive a signal with the adjacent frequency f2, the receiver temporarily stops receiving the signal with the frequency and shifts to the adjacent frequency f2 for a short time Tt1. If the signal with the frequency f2 is stable, the terminal stores the input signal with the frequency f2 in the memory for Ts. Ts is concurrent with Tpp. Then, the terminal returns to the frequency f1. It is assumed that time required for shifting to the frequency f1 and stabilizing it is Tt2. If the frequency f1 is stabilized, the terminal continues receiving the signal with the frequency f1 and searches for the adjacent frequency f2 from the signal stored in the memory. In the embodiment of the present invention, the search for the adjacent frequency f2 starts after Tt2 but it can start after Ts when storage is completed.

In accordance with the embodiment of FIG. 25, Tpp is concurrent with the time period for which the signal with an adjacent frequency is stored in the memory for search for the adjacent frequency. Therefore, the required capacity of the memory and power consumption can be reduced.

According to the present invention as described above, a terminal can acquire signals from more adjacent base stations and efficiently manage sets in a CDMA communication system. In addition, the terminal can acquire signals from adjacent base stations with reduced power consumption and hardware complexity and accurately measure the power and time delay of a received signal. Detection of a multipath and an efficient finger assignment increases the performance of a rake receiver in a spread spectrum communication system. Furthermore, by storing an input signal in a memory for processing in a terminal, the capacity of the memory and power consumption can be decreased. The entire system capacity can be increased by reducing the usual level of pilot channel power and increasing the pilot channel power for a specified short time, and a location estimation service can be offered on a forward link.

While the present invention has been described in detail with reference to the specific embodiments, they are mere exemplary applications. Thus, it is to be clearly understood that many variations can be made by anyone skilled in the art within the scope and spirit of the present invention.

CLAIMS:

1. A signal transmitting method in a base station, comprising the steps of:

transmitting a common channel signal at a first predetermined power level;

transmitting a pilot signal at a second predetermined power level, the pilot signal being transmitted at a power level greater than the second predetermined power level for a predetermined time period; and

transmitting a data channel signal.

2. The method of claim 1, wherein the pilot signal transmitted at the predetermined power level is spread by a first spreading code, and the pilot signal being transmitted at the higher power level for the predetermined time period is spread by a second spreading code.

3. The method of claim 2, wherein the pilot signal is spread by one spreading code.

4. The method of claim 2, wherein the first and second spreading codes are orthogonal codes.

5. The method of claim 4, wherein the orthogonal codes are Walsh codes.

6. The method of claim 1, wherein the predetermined time period is located at the boundary of consecutive data frames of the second signal.

7. The method of claim 6, wherein the predetermined time period occupies half of said consecutive data frames.

8. The method of claim 1, wherein the predetermined time period is set in consideration of propagation environment around the base station, arrangement of base stations, and a signal bandwidth.

9. The method of claim 7, wherein the predetermined time period represents a fraction of one data frame.

10. The method of claim 1, wherein the higher power level is equal to the overall transmission power of the base station.

11. A transmitting device for transmitting a pilot signal, a common channel signal, and a data channel signal from a base station in a mobile communication system, comprising:

a first spreader for spreading a signal by a first spreading code to generated a first pilot signal;

a second spreader for spreading a signal by a second spreading code for a predetermined time period to generate a second pilot signal;

an adder for adding the spread signals; and

a third spreader for spreading the added signal by a common spreading code.

12. The transmitting device of claim 11, wherein the different spreading codes are orthogonal codes.

13. The transmitting device of claim 11, wherein the common spreading

code is a PN code.

14. The transmitting device of claim 11, further comprising:

a time controller for controlling the gain of the pilot signal for a predetermined time period; and

a plurality of gain controllers for receiving corresponding spread pilot signals, controlling the gains of the spread pilot signals under the gain control of the time controller, and applying the result to the adder.

15. The transmitting device of claim 14, further comprising a time controller for outputting a control signal to the gain controller, for control of the output of the second spreader.

16. A base station signal transmitting/receiving method comprising the steps of:

setting a first signal on a common channel and a pilot signal on a pilot channel to a predetermined power level and a second signal on a dedicated channel to a different level according to the number of subscribers in a base station;

increasing a ratio of the transmission power of the pilot signal to the overall transmission power of the base station for a predetermined time period in the base station; and

acquiring at a terminal at least one base station signal transmitted for the predetermined time period.

17. The method of claim 16, wherein the base station increases the ratio of the transmission power of the pilot signal to the overall transmission power by increasing the transmission power of the pilot signal.

18. The method of claim 16, wherein the base station increases the ratio of the transmission power of the pilot signal to the overall transmission power by increasing the transmission power of the pilot signal and decreasing the transmission power of the data channel signal.

19. The method of claim 16, wherein the ratio of the transmission power of the pilot signal to the overall transmission power satisfies the inequality

$$\frac{pilot\ Ec + \Delta P_1}{Ior + \Delta P_2} > \frac{\text{pilot Ec}}{\text{Ior}}$$

where Ior is the normal level of the overall transmission power density of the base station

pilot Ec: energy per chip of the pilot signal on the pilot channel

P1: power increment of the pilot signal on the pilot channel, and

P2: increment of the overall transmission power of the base station

20. The method of claim 16, wherein the base station increases the ratio of the transmission power of the pilot signal to the overall transmission power by decreasing the transmission power of the data channel signal.

21. The method of claim 16, wherein the base station increases the ratio of the transmission power of the pilot signal to the overall transmission power by increasing the transmission power of the pilot signal and decreasing the transmission power of the other channel signals.

22. The method of claim 20, wherein the base station decreases the transmission power of the other channel signals to zero.

23. The method of claim 16, wherein the ratio of the transmission power of the pilot signal to the overall transmission power satisfies the inequality

$$\frac{pilot\ Ec + \Delta P_4}{Ior\ - \Delta P_3} > \frac{\text{pilot Ec}}{\text{Ior}}$$

where Ior is the normal level of the overall transmission power density of the base station

pilot Ec: energy per chip of the pilot signal on the pilot channel

P3: increment of the overall transmission power of the base station, and

P4: power increment of the pilot signal on the pilot channel

24. The method of claim 16, wherein the predetermined time period is synchronized between at least two base stations.

25. The method of claim 24, wherein the predetermined time period is the same in the at least two base stations.

26. The method of claim 24, wherein the predetermined time period is different in the at least two base stations.

27. The method of claim 24, wherein the at least two base stations maintain the ratio of the transmission power of the pilot signal to the overall transmission power of the base station at the same value.

28. A mobile communication system comprising:

a base station transmitter for transmitting a pilot signal, a common channel signal, and a data channel signal, with a ratio of the transmission power of

the pilot signal to the overall transmission power of a base station increased for a predetermined time period for signal transmission; and

a mobile station receiver for acquiring at least one base station signal transmitted from the predetermined time period.

29. The mobile communication system of claim 28, wherein the predetermined time period is located at the boundary of consecutive data frames of the second signal.

30. The mobile communication system of claim 28, wherein the ratio of the transmission power of the pilot signal to the overall transmission power satisfies the inequality

$$\frac{pilot\ Ec + \Delta P_1}{Ior + \Delta P_2} > \frac{\text{pilot Ec}}{\text{Ior}}$$

where lor is the normal level of the overall transmission power density of the base station

pilot Ec: energy per chip of the pilot signal on the pilot channel

P1: power increment of the pilot signal on the pilot channel, and

P2: increment of the overall transmission power of the base station.

31. The mobile communication system of claim 28, wherein the ratio of the transmission power of the pilot signal to the overall transmission power satisfies the inequality

$$\frac{pilot\ Ec + \Delta P_4}{Ior\ - \Delta P_3} > \frac{\text{pilot Ec}}{\text{Ior}}$$

where lor is the normal level of the overall transmission power density of the base station

pilot Ec: energy per chip of the pilot signal on the pilot channel

P3: increment of the overall transmission power of the base station, and

P4: power increment of the pilot signal on the pilot channel.

32. The mobile communication system of claim 28, wherein the pilot signal sent for the predetermined time period is spread by a first spreading code, and the pilot signal sent for the other time period is spread by a second spreading code.

33. The mobile communication system of claim 28, wherein the pilot signal is spread by one spreading code.

34. The mobile communication system of claim 32, wherein the mobile station receiver acquires the at least one base station signal received for the predetermined time period by calculating a correlation value between the first and second spreading codes.

35. A receiving device in a mobile station, comprising:

a searcher for receiving a base station signal which is sent with a changed ratio of the transmission power of a pilot signal to the overall transmission power of a base station for a predetermined time period, despreading the base station signal by a spreading code of the pilot signal, and detecting an energy from the despread signal thereby acquiring the base station signal.

36. The receiving device of claim 35, wherein the searcher comprises:

a spreading code generator for generating the first and second spreading codes;

a despreader for despreading the base station signal by the first and second spreading codes; and

an energy calculator for calculating an energy of the despread signal.

37. The receiving device of claim 36, wherein the despreader comprises:

a first multiplier for multiplying the received base station signal by a spread spectrum spreading code;

a second multiplier for multiplying a signal received from the first multiplier by the first and second spreading codes; and

a plurality of accumulators for accumulating signals received from the second multiplier in predetermined units.

38. The receiving device of claim 37, wherein the first and second spreading codes are orthogonal codes.

39. The receiving device of claim 35, wherein the pilot signal is spread by one spreading code.

40. A searcher in a mobile station receiving device which acquires a base station signal, a ratio of the transmission power of a pilot signal to the overall transmission power of a base station being increased for a predetermined time period, the device comprising:

a PN despreader for multiplying the base station signal by a PN spreading code for despreading;

a plurality of orthogonal demodulators for multiplying the despread

signal by at least two predetermined orthogonal codes and generating orthogonally demodulated signals;

a plurality of accumulators for accumulating signals received from the orthogonal demodulators in predetermined units and outputting despread signals;

a plurality of gain controllers for compensating for the gains of the corresponding despread signals;

a combiner for combining the gain-compensated signals; and

an energy calculator for obtaining the energy of the combined despread signal.

41. The searcher of claim 40, further comprising a second gain controller connected to an output terminal of the energy calculator for normalizing the gain compensation.

42. The searcher of claim 40, wherein the gain controllers multiply the corresponding despread signals by G_N* (a complex conjugate of each of the at least two predetermined orthogonal codes), for gain compensation.

43. The searcher of claim 40, wherein the gain controllers multiply the corresponding despread signals by Gi*/|Gi| where Gi is the sign of each of the at least two predetermined orthogonal codes; and

Gi* is a complex conjugate of Gi for gain compensation.

44. A searcher in a mobile station receiving device which acquires a base station signal, a ratio of the transmission power of a pilot signal to the overall transmission power of a base station being increased for a predetermined time period, the device comprising:

a PN despreader for multiplying the pilot signal received on the pilot

channel by a PN spreading code, for despreading;

an orthogonal demodulator for multiplying the despread pilot signal by a predetermined orthogonal code and generating an orthogonally demodulated signal;

a controller for assigning a path according to the signs of the orthogonal codes of the received signal;

a plurality of accumulators equal to the number of assigned path for accumulating signals distributed to the paths;

a plurality of gain controllers for compensating for the phase gains of signals received from the accumulators;

a combiner for combining signals received from the gain controllers; and

an energy calculator for obtaining the energy of a signal received from the combiner.

45. The searcher of claim 44, wherein if the orthogonal codes have the same sign, the controller assigns the output signal of the orthogonal demodulator to a first path, otherwise if the orthogonal codes have different signs, the controller assigns the output signal of the orthogonal demodulator to a second path, and the controller compensates the gain of the output of the first path accumulator by $(G0+G1)^*$ (where G0 and G1 are complex gains of the orthogonal codes) and the controller compensates for the gain of the output of the second path accumulator with $(G0-G1)^*$.

46. The searcher of claim 45, further comprising a second gain controller connected to an output terminal of the energy calculator for normalizing the gain compensation.

47. A signal transmitting/receiving method in a mobile communication system, comprising the steps of:

changing the ratio of the transmission power of a pilot signal to the overall transmission power of at least two base stations for a predetermined time period by the base stations; and

acquiring a base station signal for the predetermined time period by a terminal.

48. The method of claim 47, wherein a base station changes the ratio of the transmission power of the pilot signal to the overall transmission power by decreasing the overall transmission power, and the other base station changes the ratio of the transmission power of the pilot signal to the overall transmission power by increasing the transmission power of the pilot signal.

49. A method of acquiring signals from a plurality of base stations in a CDMA communication system, comprising the steps of:

(i) grouping the plurality of base stations into one set,

(ii) dividing the set into M subsets where M is a positive integer,

(iii) sending signals from the base stations within one of the M subsets with an overall transmission power lower than a usual level for a predetermined Nth time period where N is a positive integer,

(iv) sending signals from the other base stations at usual overall transmission power levels; and

despreading a base station signal received for the time period, thereby acquiring the base station signal by a terminal.

50. The method of claim 49, wherein there is no intersection between the subsets.

51. The method of claim 49, wherein there are intersections between the subsets.

52. A method of acquiring signals from a plurality of base stations in a CDMA communication system, comprising the steps of:

(i) grouping the plurality of base stations into one set,

(ii) dividing the set into M subsets where M is a positive integer,

(iii) sending signals from the base stations within one of the M subsets with pilot signal power higher than a usual level for a predetermined Nth time period where N is a positive integer,

(iv) sending signals from the other base stations at usual overall transmission power levels; and

despreading a base station signal received for the time period, thereby acquiring the base station signal by a terminal.

53. The method of claim 52, wherein there is no intersection between the subsets.

54. The method of claim 52, wherein there are intersections between the subsets.

55. The method of claim 47, further comprising the steps of:

receiving first signals from among pilot signals transmitted from at least two base stations by a mobile station;

measuring propagation delays of the first signals between the base stations and the mobile station;

measuring the distances between the base stations and the mobile station based on the measured propagation delays and sending information about

the distances to a base station in communication with the terminal; and

determining the location of the terminal from the base station in communication based on the information,

whereby the location of the terminal can be estimated.

56. The method of claim 47, further comprising the steps of:

receiving first signals among pilot signals transmitted from at least two base stations by a mobile station;

measuring propagation delays and signal levels of the first signals between the base stations and the mobile stations; and

performing a set management on adjacent base stations based on the measured propagation delays and signal levels,

whereby a set management is performed by the terminal.

57. A signal transmitting method in a base station, comprising the steps of:

sending a base station signal with a predetermined ratio of the transmission power of the pilot signal to the overall transmission power; and

sending the base station signal with an increased ratio of the transmission power of the pilot signal to the overall transmission power for a predetermined time period.

58. A signal transmitting method in a base station, comprising the steps of:

transmitting a pilot signal at a predetermined power level; and

transmitting a predetermined signal of a common channel signal with

an increased ratio of the transmission power of the predetermined signal to the overall transmission power of the base station is increased for a predetermined time period.

59. The method of claim 58, wherein the predetermined signal of the common channel signal includes additional information, for transmission.

60. The method of claim 58, wherein the predetermined time period is located at the boundary of consecutive data frames.

61. The method of claim 60, wherein the predetermined time period occupies half of said consecutive data frames.

62. The method of claim 58, wherein the predetermined time period is set in consideration of propagation environment around the base station, arrangement of base stations, and a signal bandwidth.

63. The method of claim 61, wherein the predetermined time period represents a fraction of one data frame.

64. The method of claim 58, wherein the base station increases the ratio of the transmission power of the predetermined signal of the common channel signal to the overall transmission power by increasing the transmission power of the predetermined signal.

65. The method of claim 58, wherein the base station increases the ratio of the transmission power of the predetermined signal of the common channel signal to the overall transmission power by increasing the transmission power of the

predetermined signal and the overall transmission power.

66. The method of claim 58, wherein the ratio of the transmission power of the predetermined signal to the overall transmission power satisfies the inequality

$$\frac{\text{pre det er min ed signal Ec} + \Delta P_{11}}{\text{Ior} + \Delta P_{22}} > \frac{\text{predetermined signal Ec}}{\text{Ior}}$$

where Ior is the normal level of the overall transmission power density of the base station

predetermined signal Ec: energy per chip of the predetermined signal on a common channel

ΔP11: power increment of the predetermined signal on a common channel, and

ΔP22: increment of the overall transmission power of the base station

67. The method of claim 58, wherein the base station increases the ratio of the transmission power of the predetermined signal of the common channel signal to the overall transmission power by decreasing the overall transmission power of the base station.

68. The method of claim 58, wherein the base station increases the ratio of the transmission power of the predetermined signal of the common channel signal to the overall transmission power by increasing the transmission power of the predetermined signal of the common channel signal and decreasing the overall

transmission power.

69. The method of claim 58, wherein the ratio of the transmission power of the predetermined signal of the common channel signal to the overall transmission power satisfies the inequality

$$\frac{\text{pre det er min ed signal Ec} + \Delta P_{44}}{\text{Ior} + \Delta P_{33}} > \frac{\text{predetermined signal Ec}}{\text{Ior}}$$

where Ior is the normal level of the overall transmission power density of the base station

predetermined signal Ec: energy per chip of the predetermined signal on a common channel

ΔP33: increment of the overall transmission power of the base station, and

ΔP44: power increment of the predetermined signal on a common channel.

70. A signal transmitting method for transmitting common channel signals and data channel signals from a base station in a mobile communication system, comprising the steps of:

transmitting the data channel signals; and

changing the transmission power of a predetermined common channel signal to the overall transmission power of the base station for a predetermined time period.

71. The method of claim 70, wherein the predetermined signal of the common channel signal includes additional information, for transmission.

72. The method of claim 70, wherein the ratio of the transmission power of the predetermined signal to the overall transmission power satisfies the inequality

$$\frac{\text{predetermined signal Ec} + \Delta P_{11}}{\text{Ior} + \Delta P_{22}} > \frac{\text{predetermined signal Ec}}{\text{Ior}}$$

where Ior is the normal level of the overall transmission power density of the base station

predetermined signal Ec: energy per chip of the predetermined signal on a common channel

ΔP11: power increment of the predetermined signal on a common channel, and

ΔP22: increment of the overall transmission power of the base station

73. The method of claim 70, wherein the ratio of the transmission power of the predetermined signal of the common channel signal to the overall transmission power satisfies the inequality

$$\frac{\text{predetermined signal Ec} + \Delta P_{44}}{\text{Ior} + \Delta P_{33}} > \frac{\text{predetermined signal Ec}}{\text{Ior}}$$

where Ior is the normal level of the overall transmission power density of the base station

predetermined signal Ec: energy per chip of the predetermined signal

on a common channel

$\Delta P33$: increment of the overall transmission power of the base station, and

$\Delta P44$: power increment of the predetermined signal on a common channel.

74. A base station signal transmitting/receiving method comprising the steps of:

transmitting a base station signal with a changed ratio of the transmission power of a predetermined common channel signal to the overall transmission power of a base station for a predetermined time period; and

acquiring at a terminal at least one base station signal transmitted for the predetermined time period.

75. The method of claim 74, wherein the predetermined time period is synchronized between at least two base stations when there are at least two base stations in the vicinity of the terminal.

76. The method of claim 75, wherein the predetermined time period is different in the at least two base stations.

77. The method of claim 75, wherein the predetermined time period is the same in the at least two base stations.

78. The method of claim 75, wherein the at least two base stations maintain the ratio of the transmission power of the predetermined signal of the common channel signal to the overall transmission power of the base station at the same value.

79. The method of claim 75, wherein the predetermined signal of the common channel signal includes additional information, for transmission.

80. The method of claim 74, wherein the ratio of the transmission power of the predetermined signal to the overall transmission power satisfies the inequality

$$\frac{\text{pre det er min ed signal Ec} + \Delta P_{11}}{\text{Ior} + \Delta P_{22}} > \frac{\text{predetermined signal Ec}}{\text{Ior}}$$

where lor is the normal level of the overall transmission power density of the base station

predetermined signal Ec: energy per chip of the predetermined signal on a common channel

ΔP11: power increment of the predetermined signal on a common channel, and

ΔP22: increment of the overall transmission power of the base station

81. The method of claim 74, wherein the ratio of the transmission power of the predetermined signal of the common channel signal to the overall transmission power satisfies the inequality

$$\frac{\text{pre det er min ed signal Ec} + \Delta P_{44}}{\text{Ior} + \Delta P_{33}} > \frac{\text{predetermined signal Ec}}{\text{Ior}}$$

where lor is the normal level of the overall transmission power density of the base station

predetermined signal Ec: energy per chip of the predetermined signal

on a common channel

ΔP33: increment of the overall transmission power of the base station, and

ΔP44: power increment of the predetermined signal on a common channel.

82. A base station signal transmitting/receiving device comprising:

a base station transmitter for transmitting a signal with a changed ratio of the transmission power of a predetermined common channel signal to the overall transmission power of a base station for a predetermined time period; and

a mobile station receiver for acquiring at least one base station signal transmitted for the predetermined time period.

83. A base station signal transmitting/receiving device comprising:

a base station transmitter for transmitting a signal, the ratio of the transmission power of a predetermined common channel signal to the overall transmission power of a base station being changed and a pilot signal being at a predetermined power level, for a predetermined time period; and

a mobile station receiver for acquiring at least one base station signal transmitted for the predetermined time period.

84. A base station signal transmitting method in a mobile communication system having a pilot signal and at least one data channel, comprising the step of:

transmitting the pilot signal at a predetermined power level; and

increasing the transmission power of the pilot signal for a predetermined time period.

85. The method of claim 84, wherein the predetermined time period is

located at the boundary between frames of the data channel.

86. The method of claim 84, wherein the transmission power of the pilot signal is periodically increased for the predetermined time period.

87. The method of clam 84, further comprising the step of notifying a mobile station of the predetermined time period by a base station.

88. The method of claim 84, wherein the transmission power of at least one of the other channel signals is decreased for the predetermined time period when the transmission power of the pilot signal is increased.

89. The method of claim 84, wherein transmission of at least one of the other channel signals is stopped for the predetermined time period when the transmission power of the pilot signal is increased.

90. A base station signal transmitting method in a mobile communication system having at least one pilot signal and at least one data channel, comprising the steps of:

stopping transmission of the pilot signal for a first time period; and

transmitting the pilot signal for a second time period.

91. The method of claim 90, wherein the second time period is located at the boundary between frames of the data channel.

92. The method of claim 90, wherein the transmission power of the pilot signal is periodically increased for the second time period.

93. The method of clam 90, further comprising the step of notifying a mobile station of the second time period by a base station.

94. The method of claim 90, wherein the transmission power of at least one of the other channel signals is decreased for the second time period when the transmission power of the pilot signal is increased.

95. The method of claim 90, wherein transmission of at least one of the other channel signals is stopped for the second time period when the transmission power of the pilot signal is increased.

96. The method of claim 1, wherein the transmission power of one of the common channel signal and the data channel signal is decreased for the predetermined time period.

97. The transmitting device of claim 11, wherein the transmission power of one of the common channel signal and the data channel signal is decreased for the time period when the second pilot signal is transmitted.

98. The transmitting device of claim 97, wherein the time period is located over the former part of a frame and the latter part of the following frame.

99. The method of claim 24, wherein while one of the at least two base stations increases the transmission power of the pilot signal, the other base station decreases the overall transmission power.

100. The method of claim 48, wherein the ratio of the transmission power of a next pilot signal to be transmitted to the overall transmission power is changed

by decreasing the overall transmission power in a different base station, and increasing the overall transmission power in the other base stations.

101. The method of claim 58, wherein the predetermined common channel signal is transmitted only for a predetermined time period.

102. The method of claim 70, wherein the predetermined signal is transmitted only for the predetermined time period.

103. The method of claim 74, wherein the predetermined signal is transmitted only for the predetermined time period.

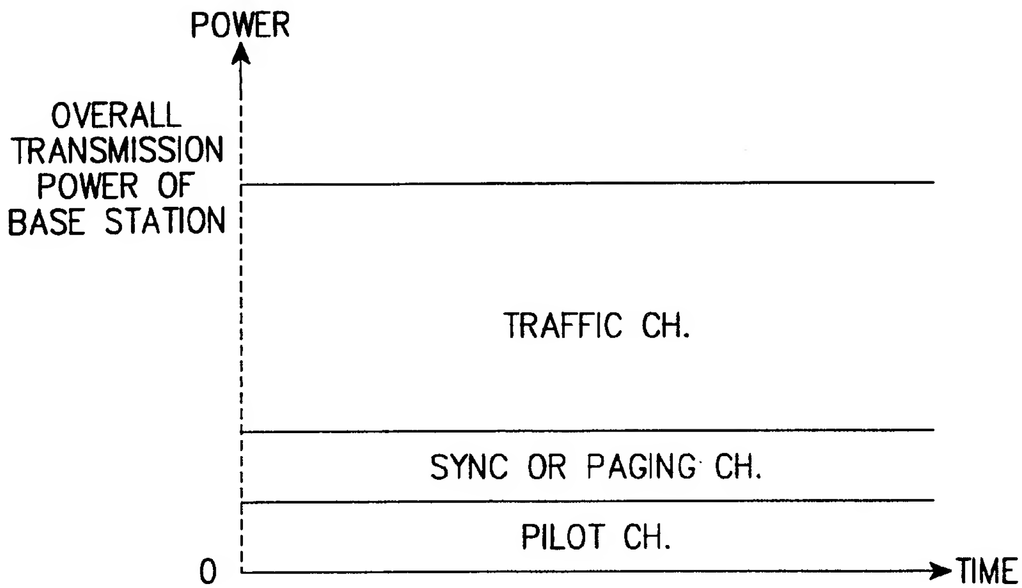
POWER
OVERALL TRANSMISSION POWER OF BASE STATION
TRAFFIC CH.
SYNC OR PAGING CH.
PILOT CH.
0
TIME

FIG. 1

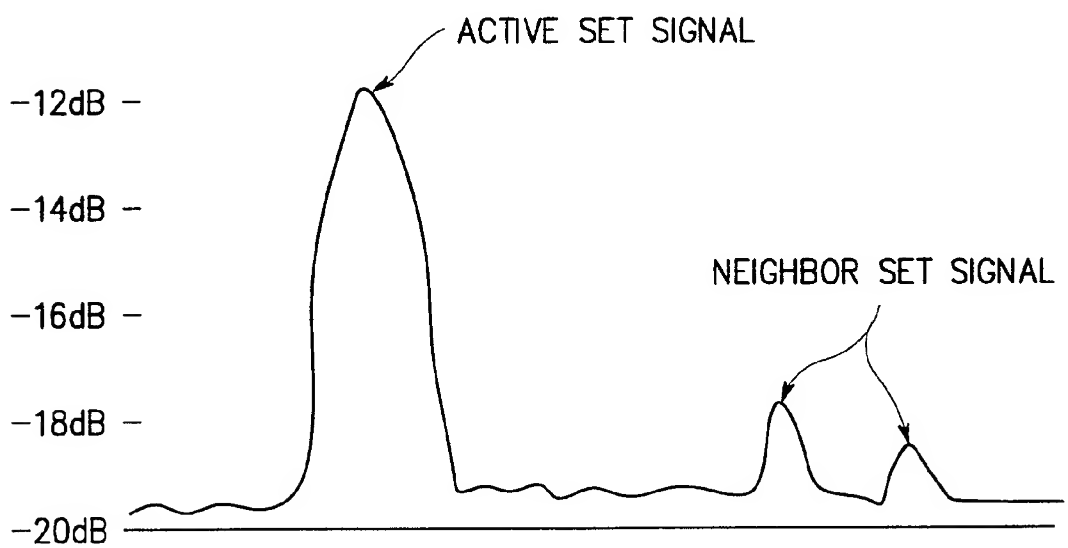
ACTIVE SET SIGNAL
-12dB
-14dB
-16dB
-18dB
-20dB
NEIGHBOR SET SIGNAL

FIG. 2

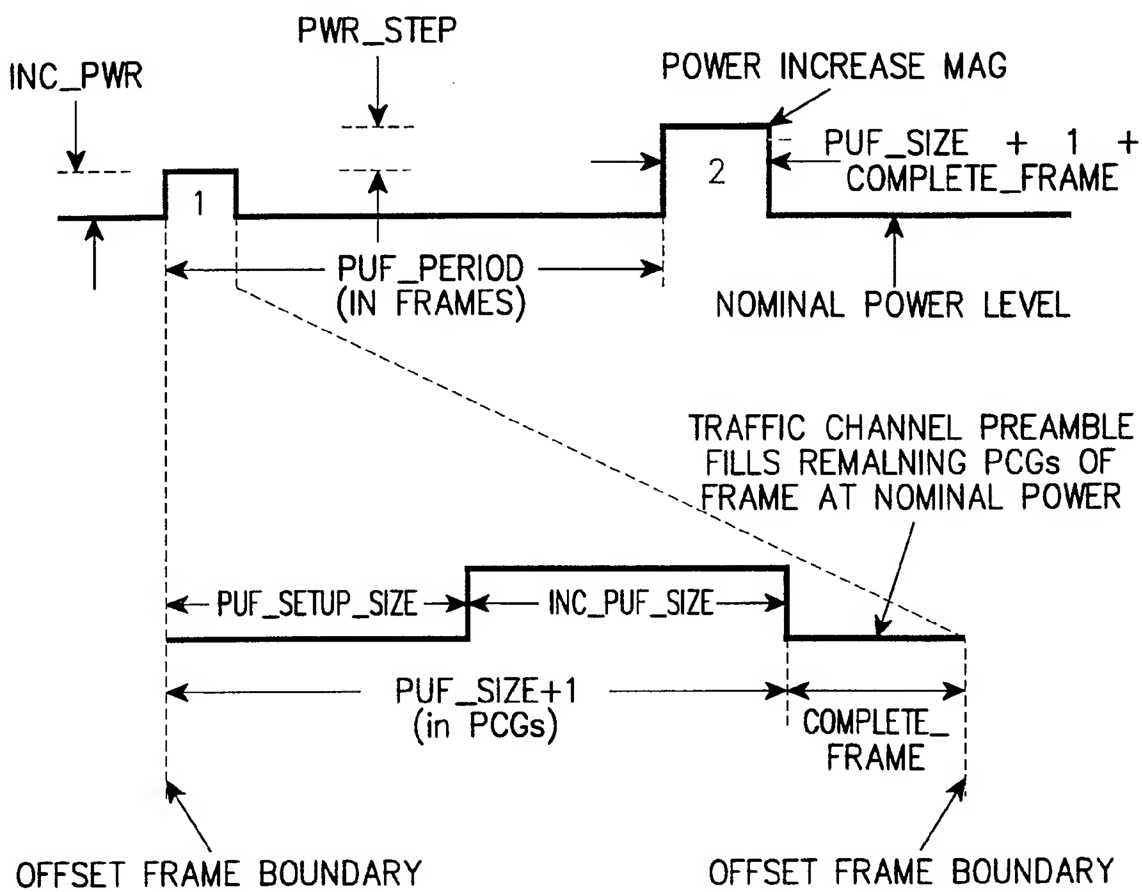
PWR_STEP
INC_PWR
POWER INCREASE MAG
PUF_SIZE + 1 + COMPLETE_FRAME
1
2
PUF_PERIOD (IN FRAMES)
NOMINAL POWER LEVEL
TRAFFIC CHANNEL PREAMBLE FILLS REMALNING PCGs OF FRAME AT NOMINAL POWER
PUF_SETUP_SIZE
INC_PUF_SIZE
PUF_SIZE+1 (in PCGs)
COMPLETE_ FRAME
OFFSET FRAME BOUNDARY
OFFSET FRAME BOUNDARY

FIG. 3

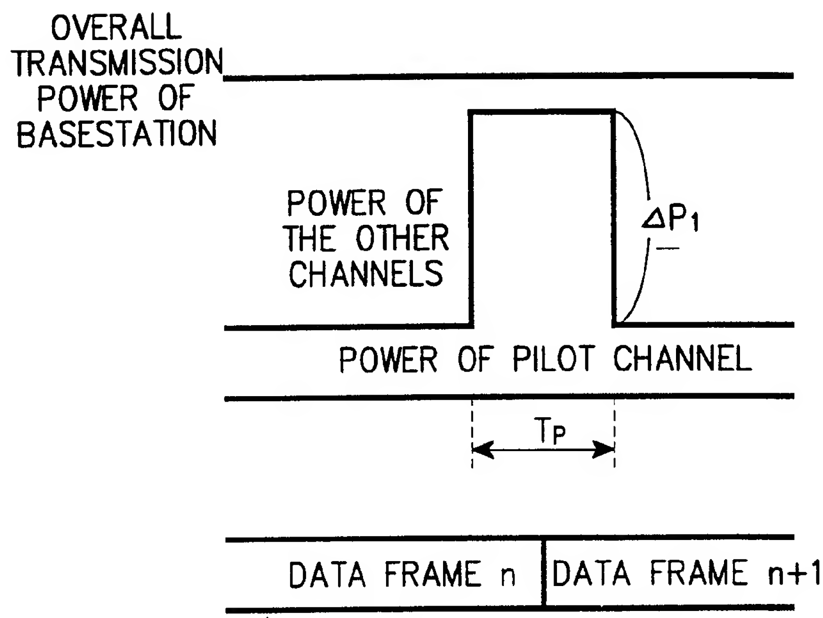
OVERALL TRANSMISSION POWER OF BASESTATION
POWER OF THE OTHER CHANNELS
ΔP1
POWER OF PILOT CHANNEL
TP
DATA FRAME n
DATA FRAME n+1

FIG. 4A

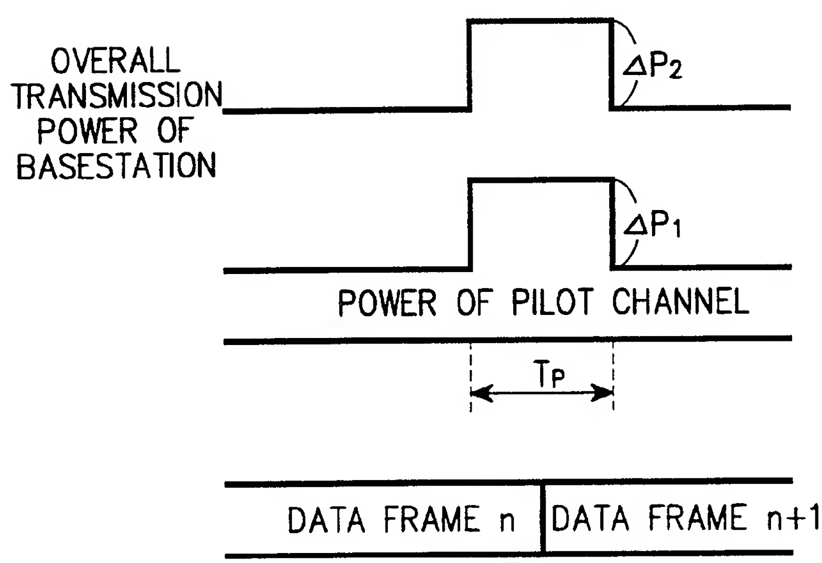
OVERALL TRANSMISSION POWER OF BASESTATION
ΔP2
ΔP1
POWER OF PILOT CHANNEL
TP
DATA FRAME n
DATA FRAME n+1

FIG. 4B

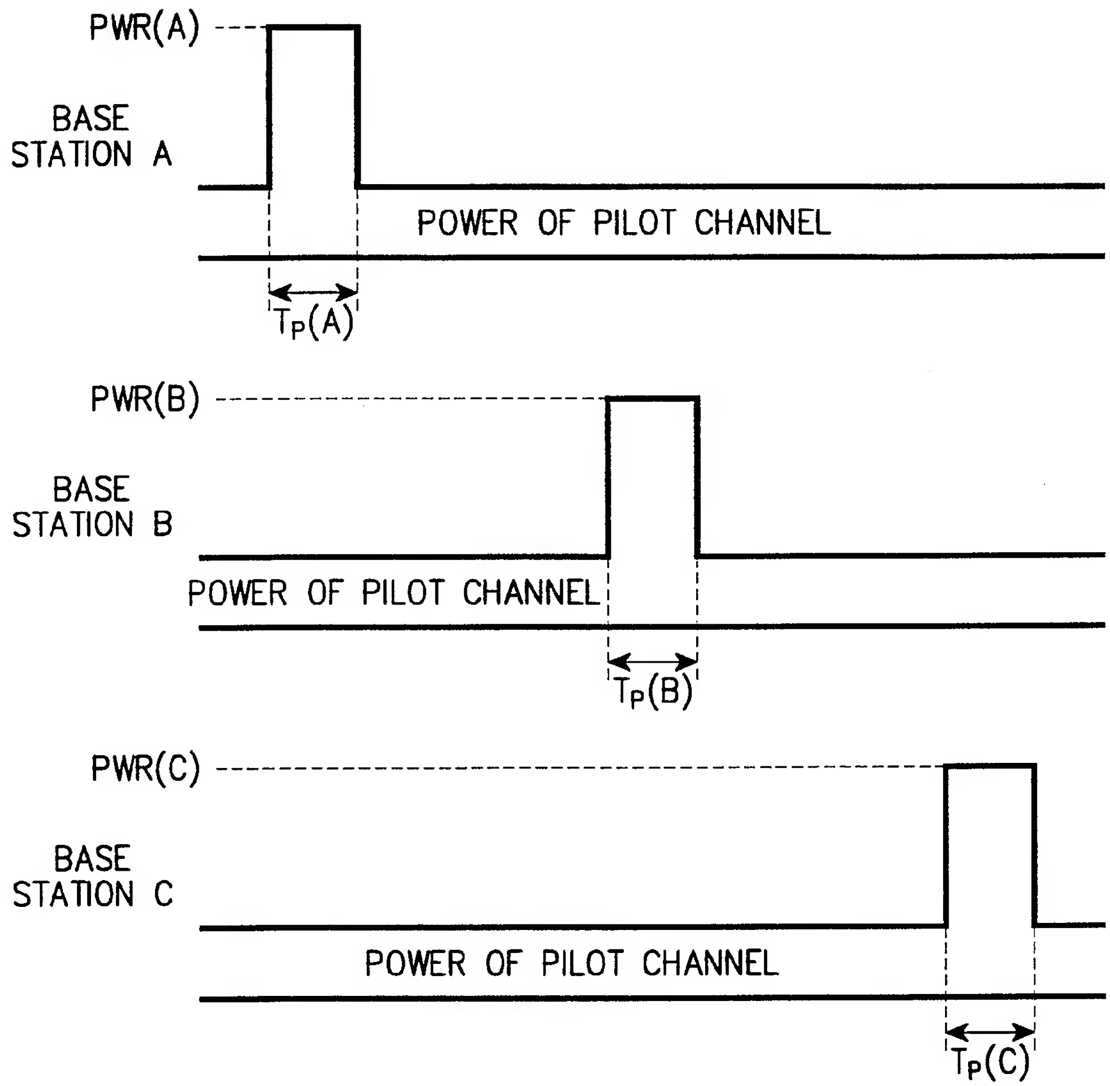
PWR(A)
BASE STATION A
POWER OF PILOT CHANNEL
$T_P(A)$
PWR(B)
BASE STATION B
POWER OF PILOT CHANNEL
$T_P(B)$
PWR(C)
BASE STATION C
POWER OF PILOT CHANNEL
$T_P(C)$

FIG. 5A

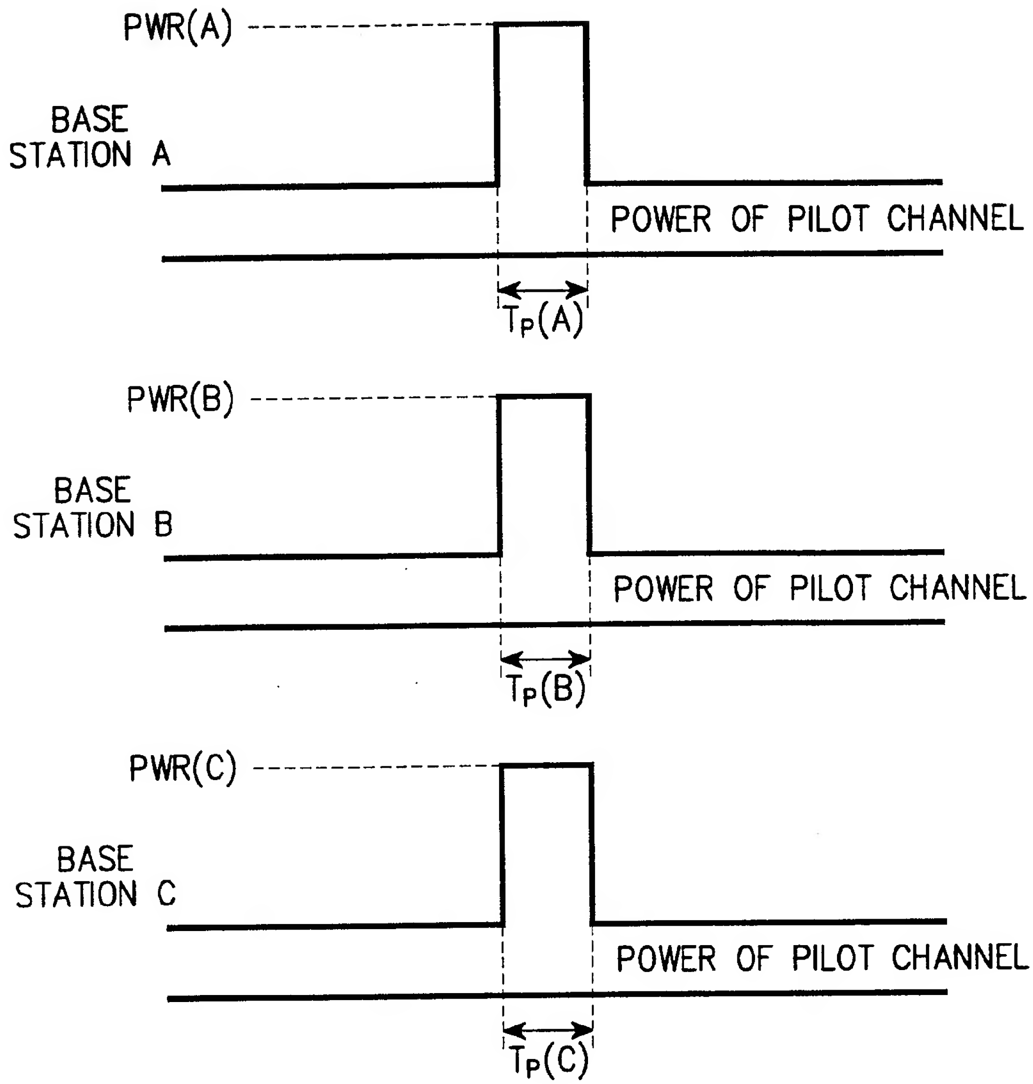
PWR(A)
BASE STATION A
POWER OF PILOT CHANNEL
$T_P(A)$
PWR(B)
BASE STATION B
POWER OF PILOT CHANNEL
$T_P(B)$
PWR(C)
BASE STATION C
POWER OF PILOT CHANNEL
$T_P(C)$

FIG. 5B

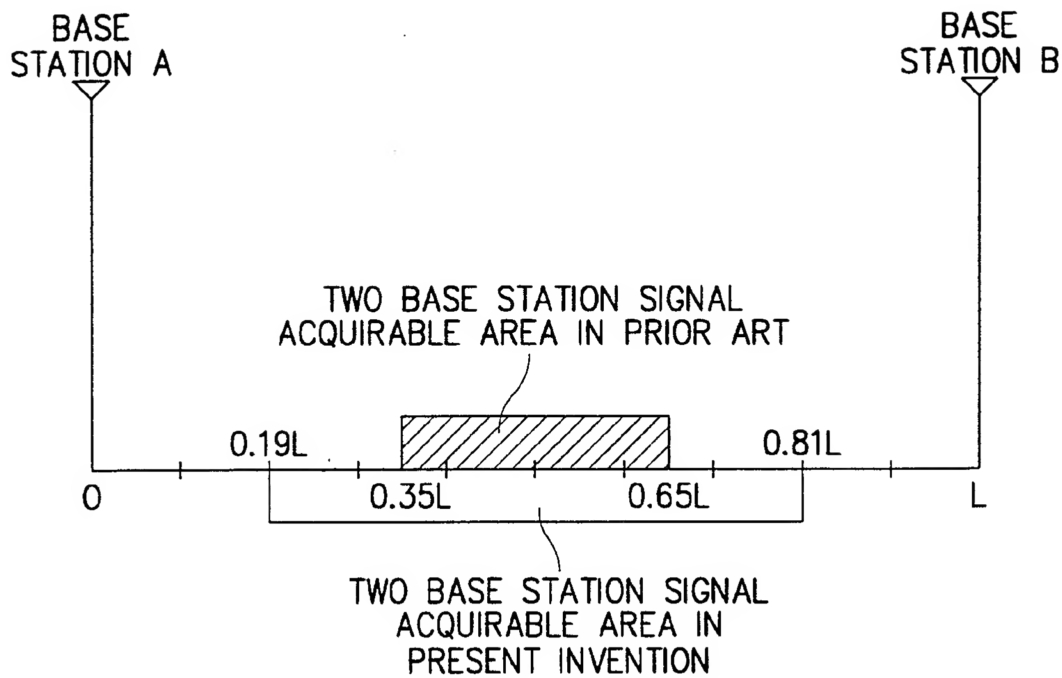
BASE
STATION A
BASE
STATION B
TWO BASE STATION SIGNAL
ACQUIRABLE AREA IN PRIOR ART
0.19L
0.81L
0
0.35L
0.65L
L
TWO BASE STATION SIGNAL
ACQUIRABLE AREA IN
PRESENT INVENTION

FIG. 6

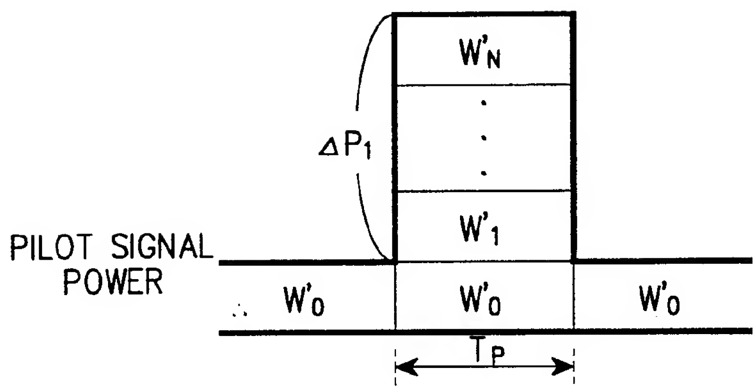

FIG. 7

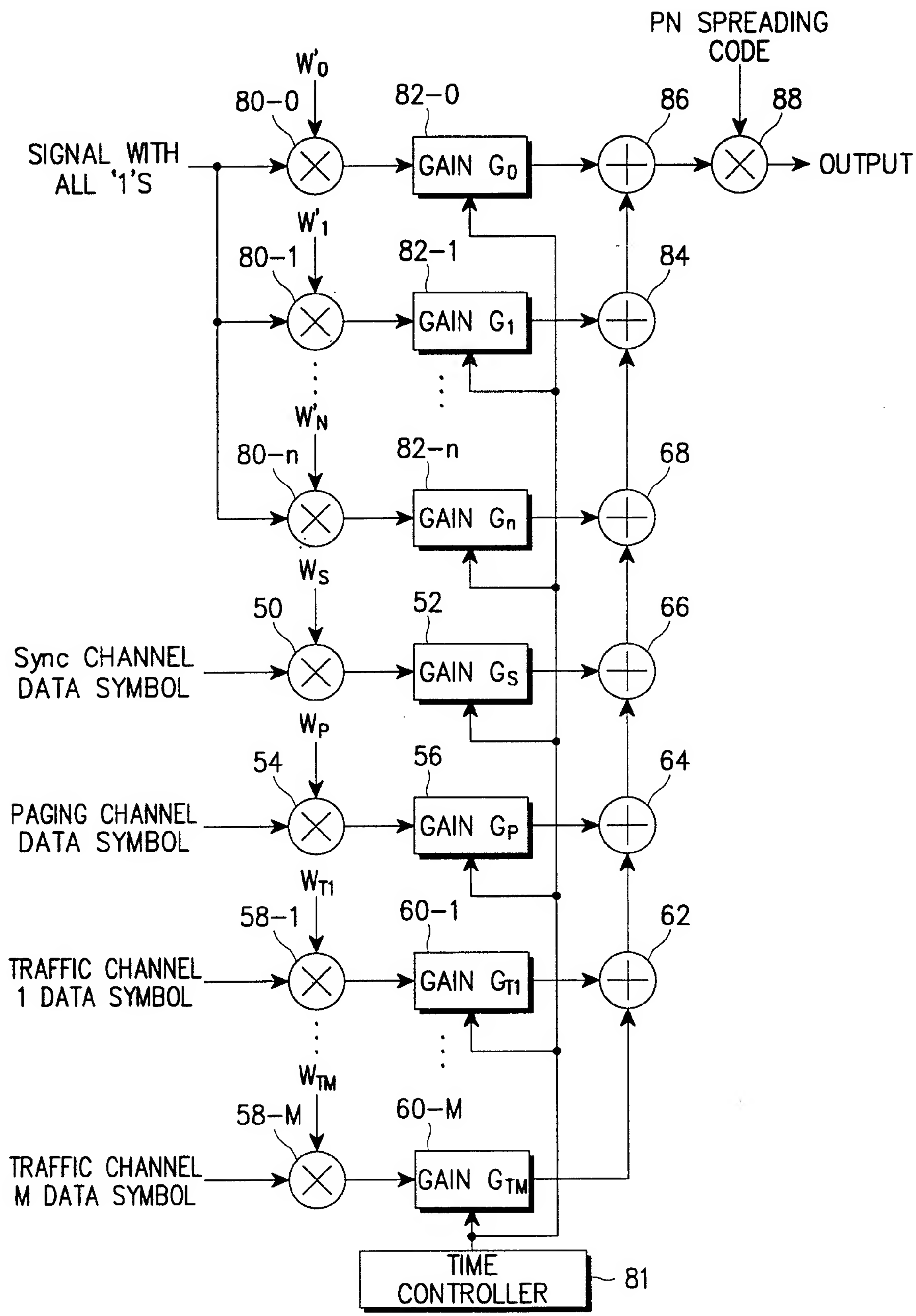
PN SPREADING CODE
W'0
80-0
82-0
86
88
SIGNAL WITH ALL '1'S
GAIN G0
OUTPUT
W'1
80-1
82-1
84
GAIN G1
W'N
80-n
82-n
68
GAIN Gn
WS
50
52
66
Sync CHANNEL DATA SYMBOL
GAIN GS
WP
54
56
64
PAGING CHANNEL DATA SYMBOL
GAIN GP
WT1
58-1
60-1
62
TRAFFIC CHANNEL 1 DATA SYMBOL
GAIN GT1
WTM
58-M
60-M
TRAFFIC CHANNEL M DATA SYMBOL
GAIN GTM
TIME CONTROLLER
81

FIG. 8

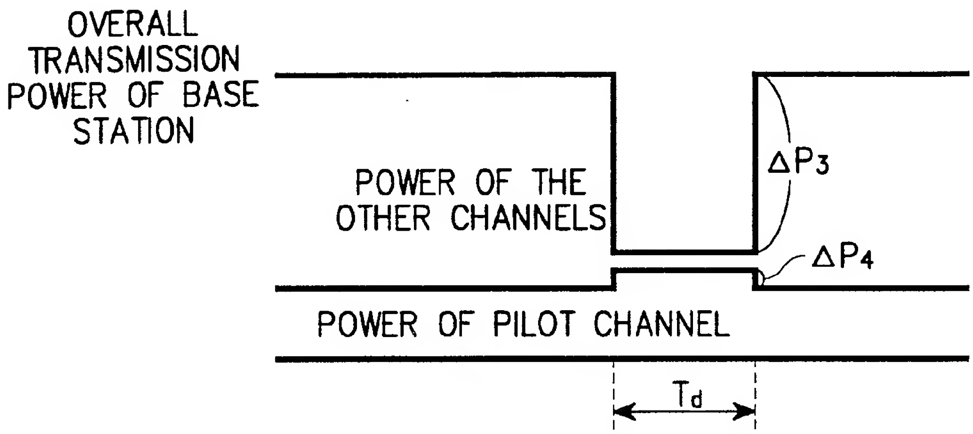
OVERALL TRANSMISSION POWER OF BASE STATION
POWER OF THE OTHER CHANNELS
ΔP3
ΔP4
POWER OF PILOT CHANNEL
Td

FIG. 9A

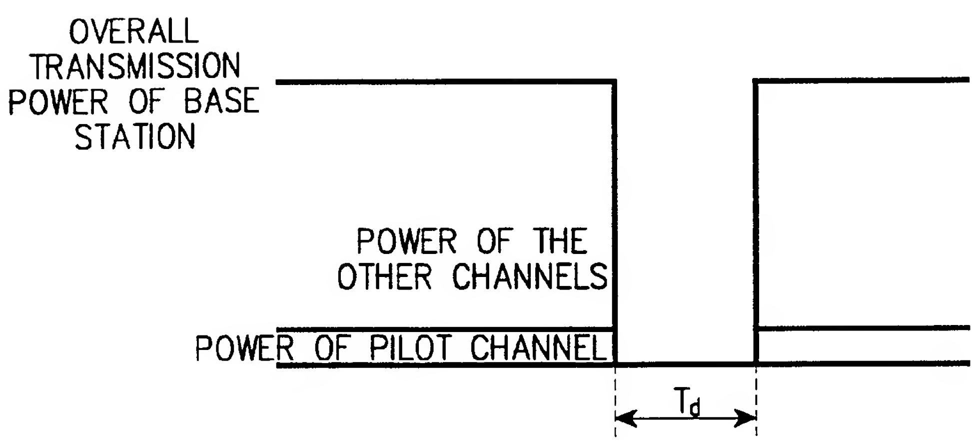
OVERALL TRANSMISSION POWER OF BASE STATION
POWER OF THE OTHER CHANNELS
POWER OF PILOT CHANNEL
Td

FIG. 9B

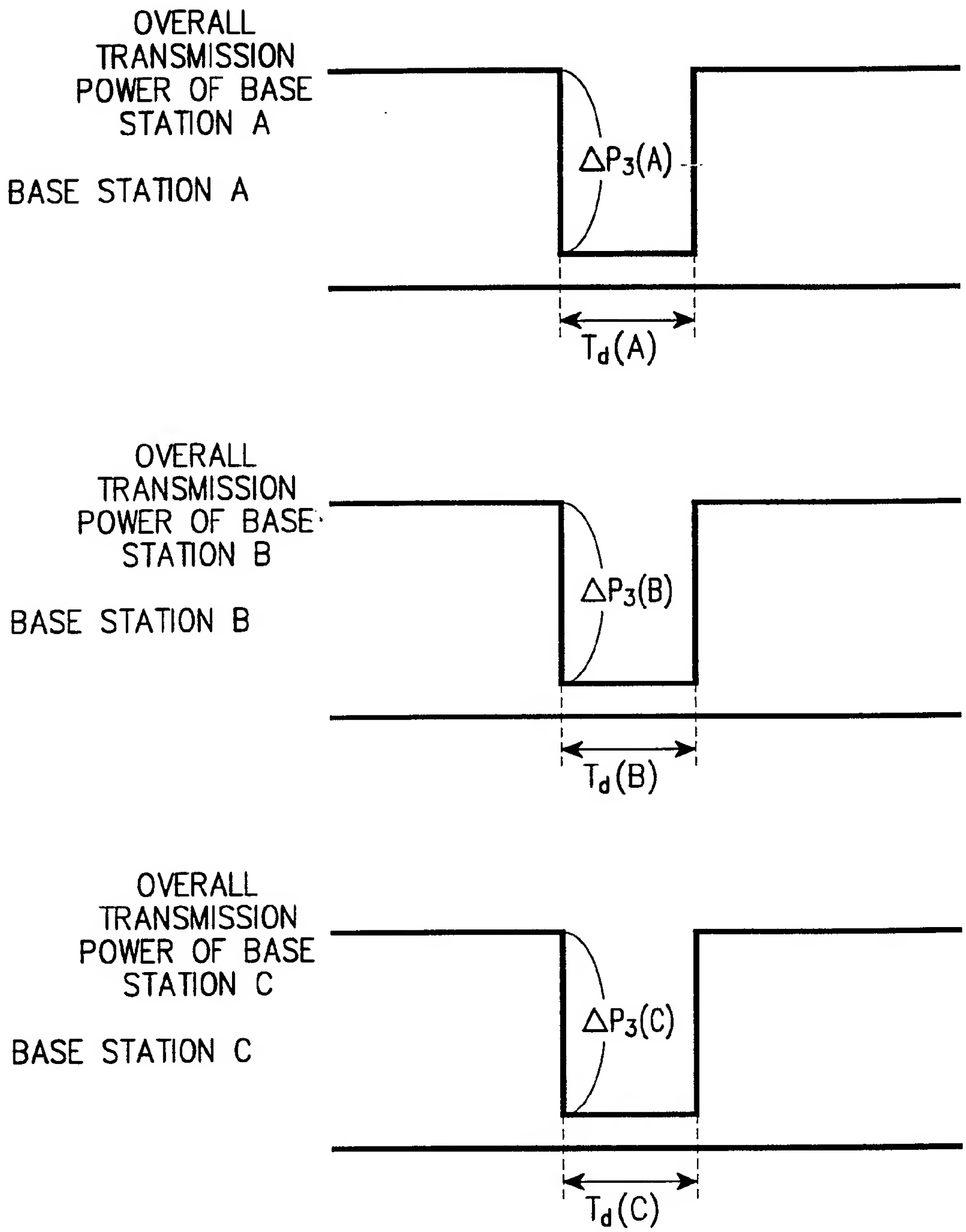
OVERALL TRANSMISSION POWER OF BASE STATION A
BASE STATION A
ΔP3(A)
Td(A)
OVERALL TRANSMISSION POWER OF BASE STATION B
BASE STATION B
ΔP3(B)
Td(B)
OVERALL TRANSMISSION POWER OF BASE STATION C
BASE STATION C
ΔP3(C)
Td(C)

FIG. 10A

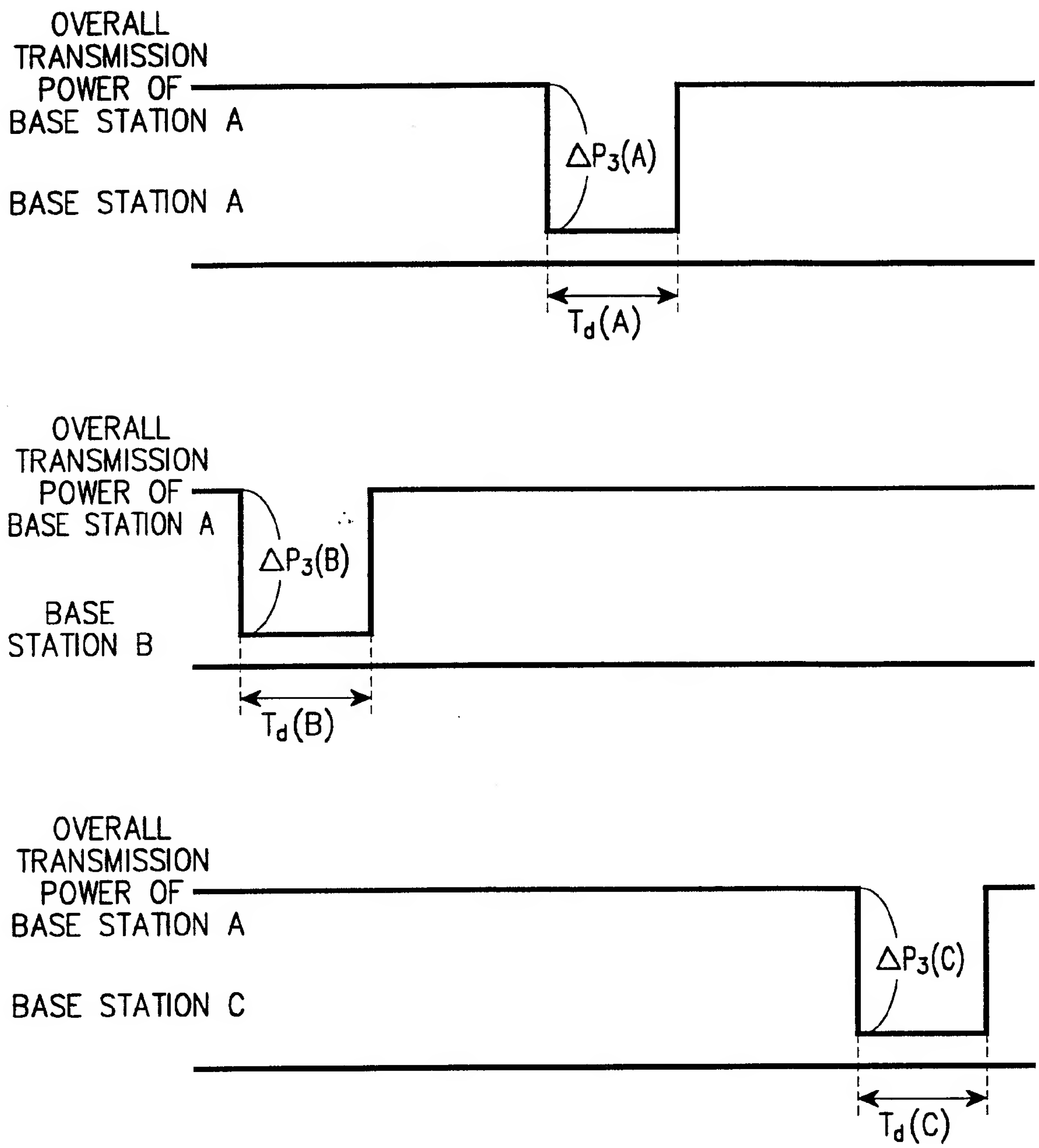
OVERALL TRANSMISSION POWER OF BASE STATION A
BASE STATION A
$\Delta P_3(A)$
$T_d(A)$
OVERALL TRANSMISSION POWER OF BASE STATION A
BASE STATION B
$\Delta P_3(B)$
$T_d(B)$
OVERALL TRANSMISSION POWER OF BASE STATION A
BASE STATION C
$\Delta P_3(C)$
$T_d(C)$

FIG. 10B

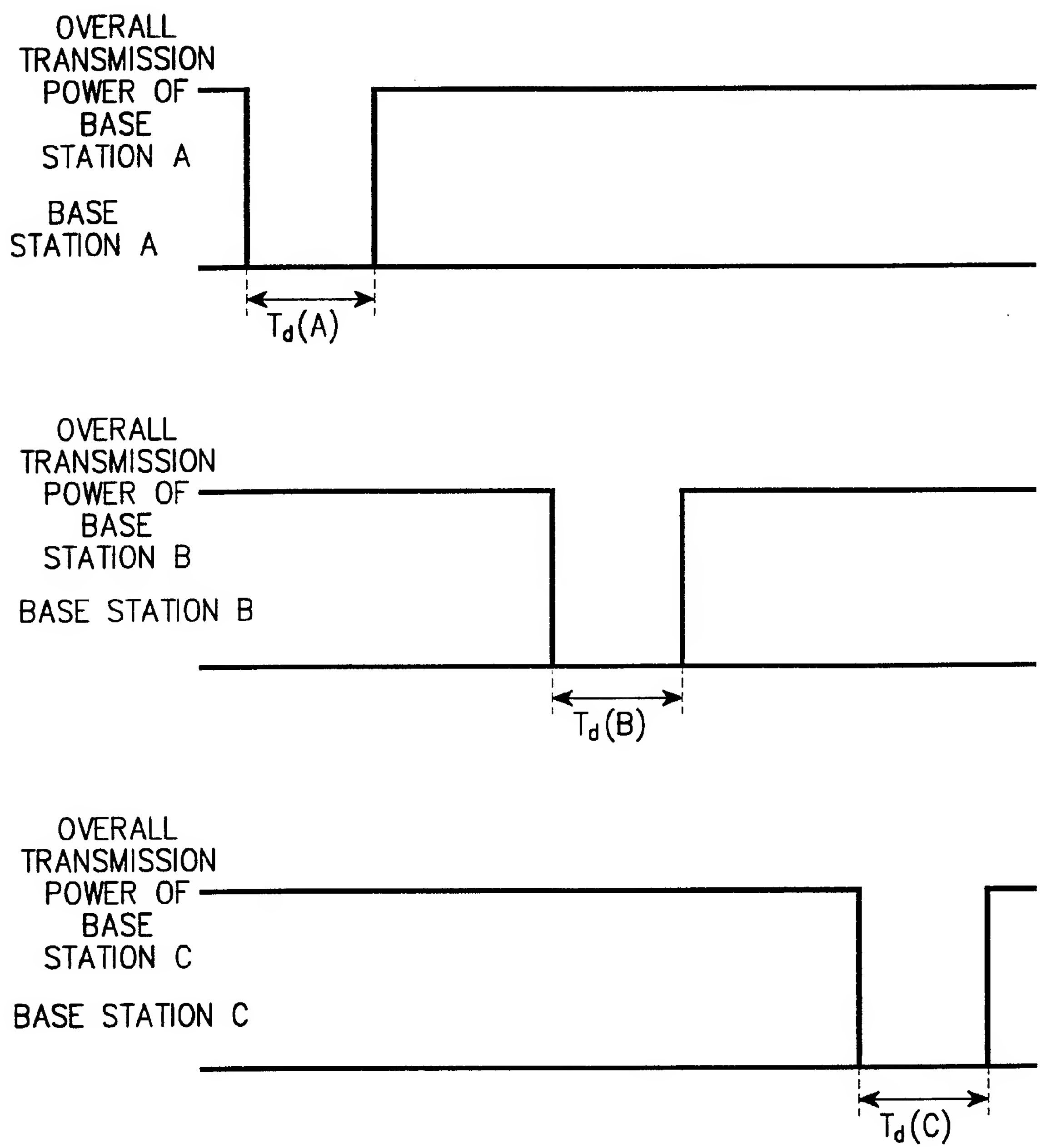
OVERALL
TRANSMISSION
POWER OF
BASE
STATION A
BASE
STATION A
$T_d(A)$
OVERALL
TRANSMISSION
POWER OF
BASE
STATION B
BASE STATION B
$T_d(B)$
OVERALL
TRANSMISSION
POWER OF
BASE
STATION C
BASE STATION C
$T_d(C)$

FIG. 10C

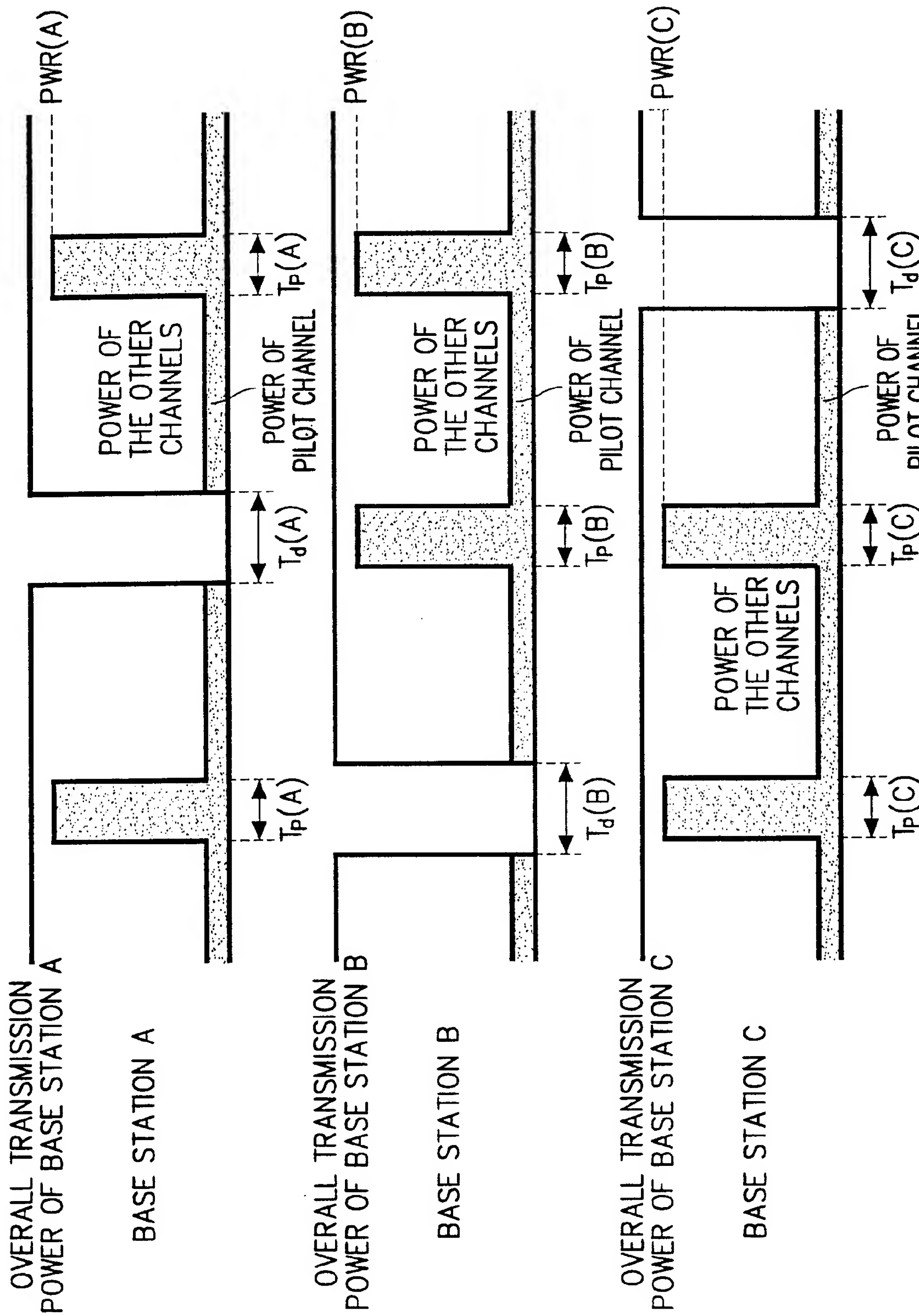
OVERALL TRANSMISSION POWER OF BASE STATION A
BASE STATION A
PWR(A)
POWER OF THE OTHER CHANNELS
POWER OF PILOT CHANNEL
$T_P(A)$
$T_d(A)$
OVERALL TRANSMISSION POWER OF BASE STATION B
BASE STATION B
PWR(B)
POWER OF THE OTHER CHANNELS
POWER OF PILOT CHANNEL
$T_P(B)$
$T_d(B)$
OVERALL TRANSMISSION POWER OF BASE STATION C
BASE STATION C
PWR(C)
POWER OF THE OTHER CHANNELS
POWER OF PILOT CHANNEL
$T_P(C)$
$T_d(C)$

FIG. 11A

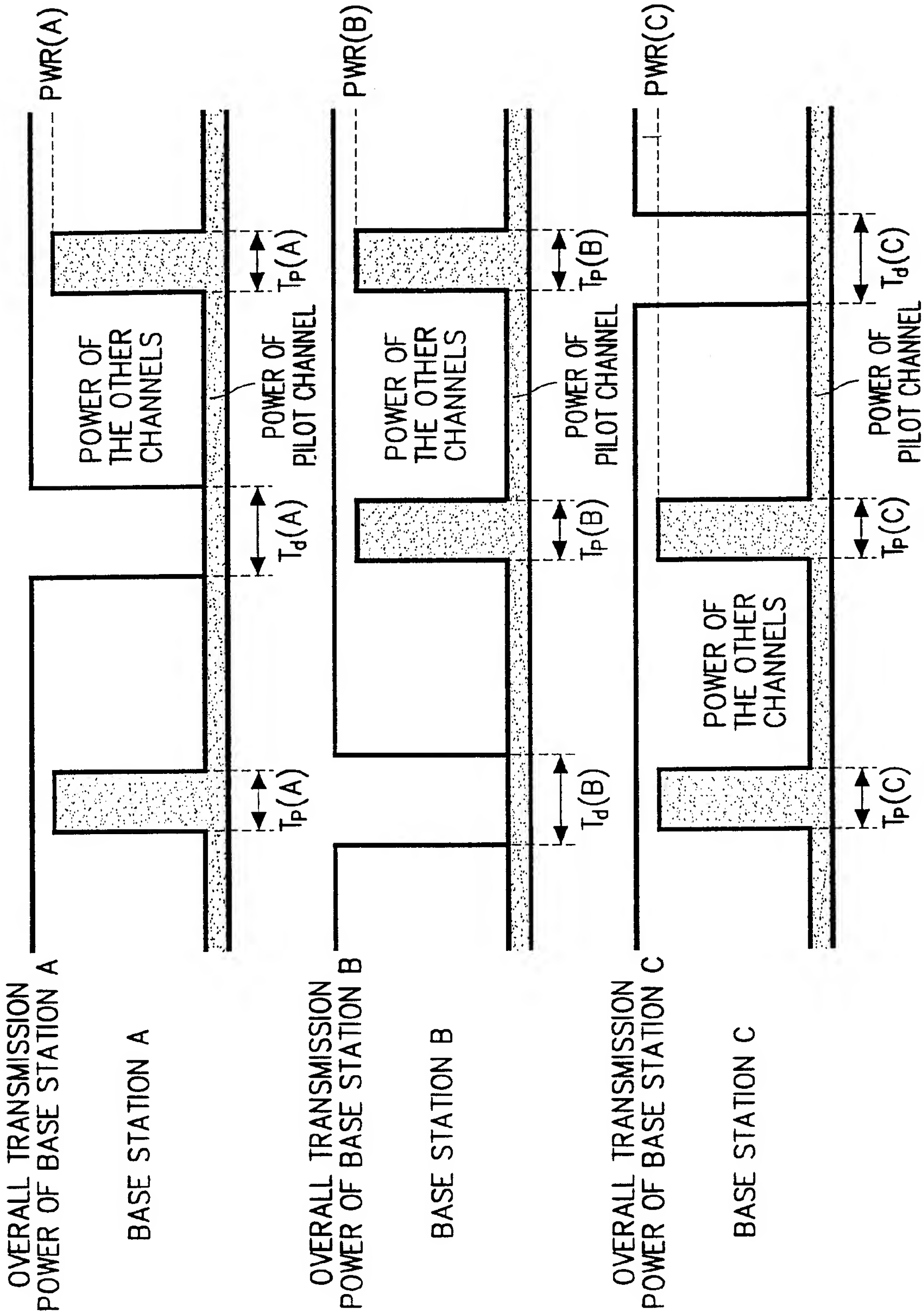
OVERALL TRANSMISSION POWER OF BASE STATION A
BASE STATION A
PWR(A)
POWER OF THE OTHER CHANNELS
POWER OF PILOT CHANNEL
$T_P(A)$
$T_d(A)$
$T_P(A)$
OVERALL TRANSMISSION POWER OF BASE STATION B
BASE STATION B
PWR(B)
POWER OF THE OTHER CHANNELS
POWER OF PILOT CHANNEL
$T_P(B)$
$T_P(B)$
$T_d(B)$
OVERALL TRANSMISSION POWER OF BASE STATION C
BASE STATION C
PWR(C)
POWER OF THE OTHER CHANNELS
POWER OF PILOT CHANNEL
POWER OF THE OTHER CHANNELS
$T_d(C)$
$T_P(C)$
$T_P(C)$

FIG. 11B

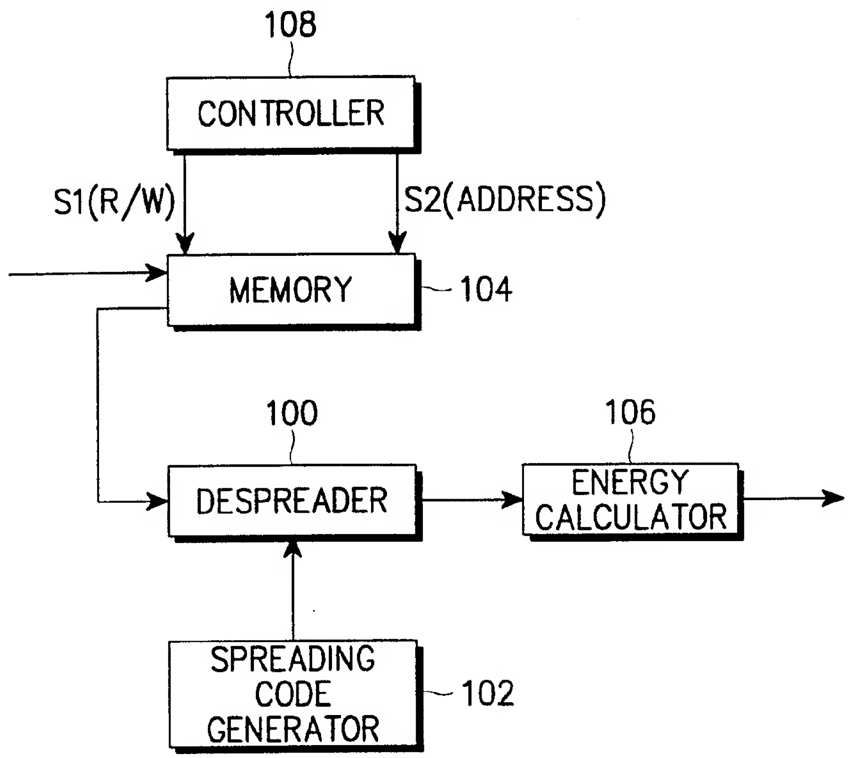
108
CONTROLLER
S1(R/W)
S2(ADDRESS)
MEMORY
104
100
DESPREADER
106
ENERGY CALCULATOR
SPREADING CODE GENERATOR
102

FIG. 12

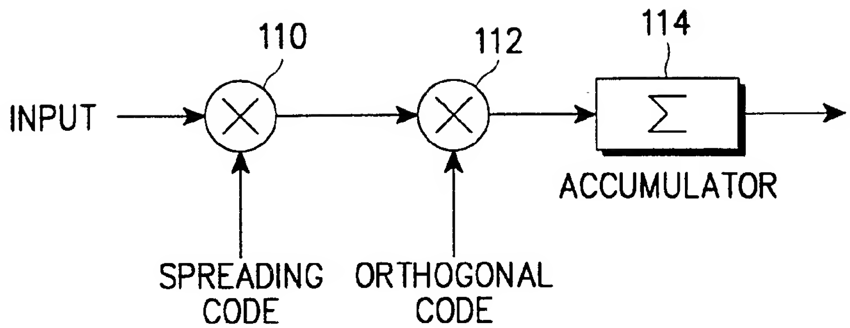
110
112
114
INPUT
Σ
ACCUMULATOR
SPREADING CODE
ORTHOGONAL CODE

FIG. 13

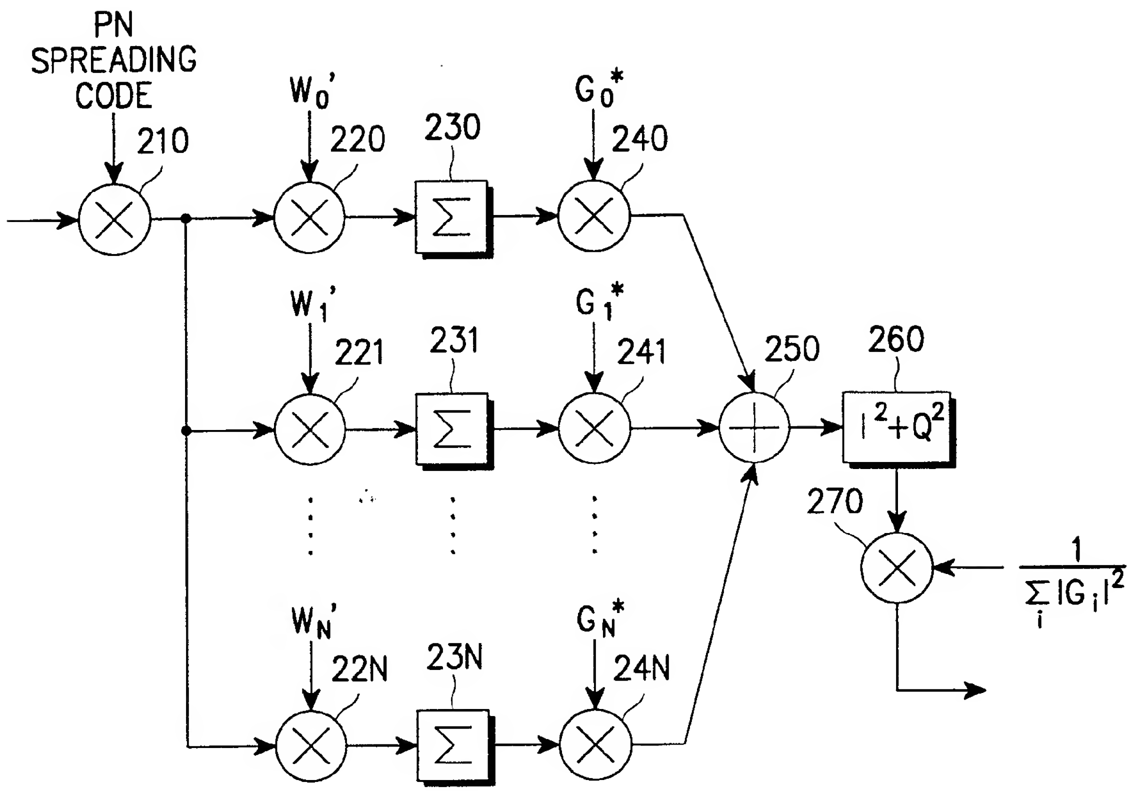
PN
SPREADING
CODE
210
W0'
220
230
G0*
240
W1'
221
231
G1*
241
250
260
I2+Q2
270
WN'
22N
23N
GN*
24N
1
ΣiIGiI2

FIG. 14

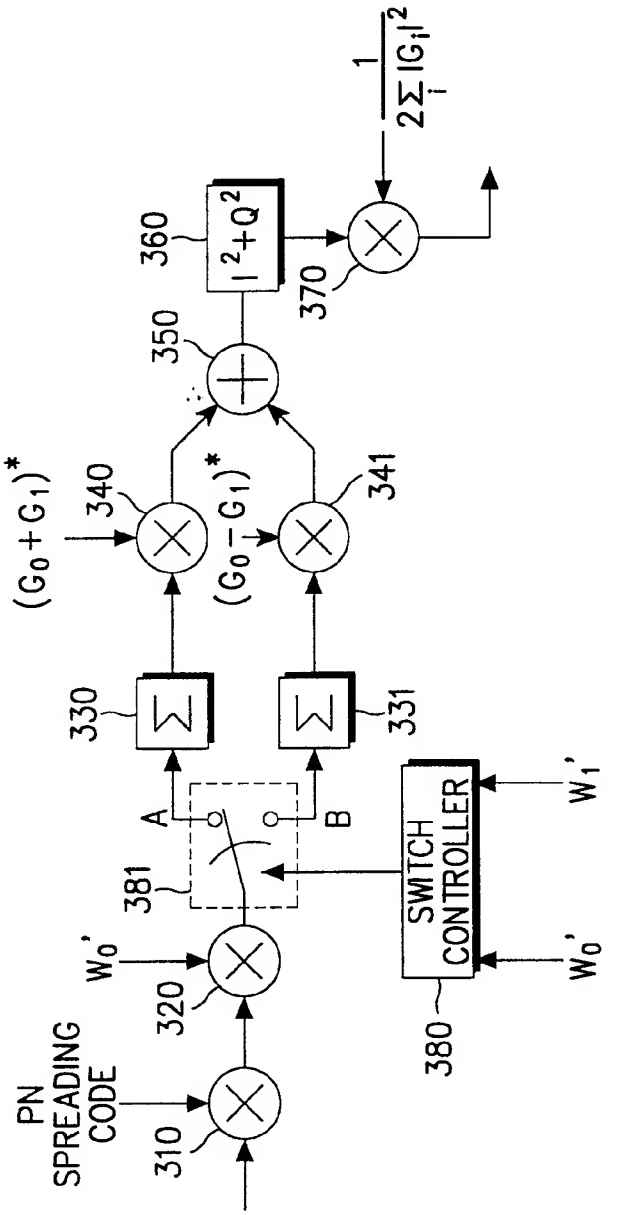
PN SPREADING CODE
310
320
W_0'
381
A
B
330
331
$(G_0+G_1)^*$
$(G_0-G_1)^*$
340
341
350
360
I^2+Q^2
370
$\frac{1}{2\sum_i |G_i|^2}$
SWITCH CONTROLLER
380
W_0'
W_1'

FIG. 15

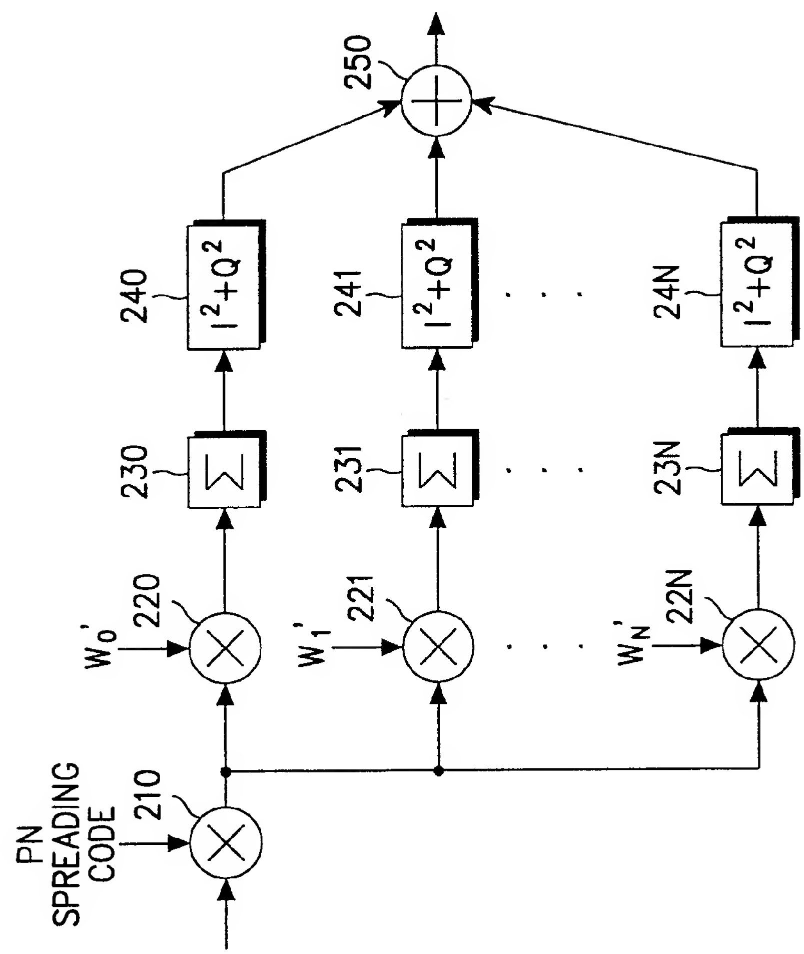
PN
SPREADING
CODE
210
W0'
220
W1'
221
WN'
22N
230
231
23N
240
241
24N
I²+Q²
I²+Q²
I²+Q²
250

FIG. 16

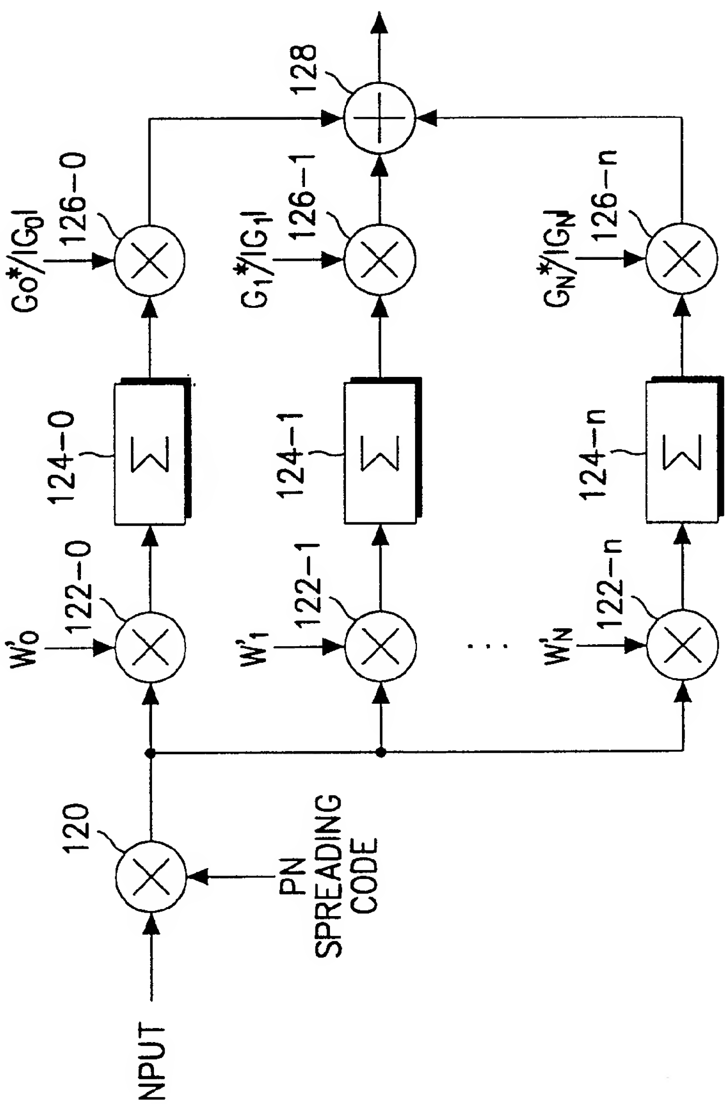
INPUT
PN SPREADING CODE
120
W'0
122-0
124-0
G0*/|G0|
126-0
W'1
122-1
124-1
G1*/|G1|
126-1
W'N
122-n
124-n
GN*/|GN|
126-n
128

FIG. 17

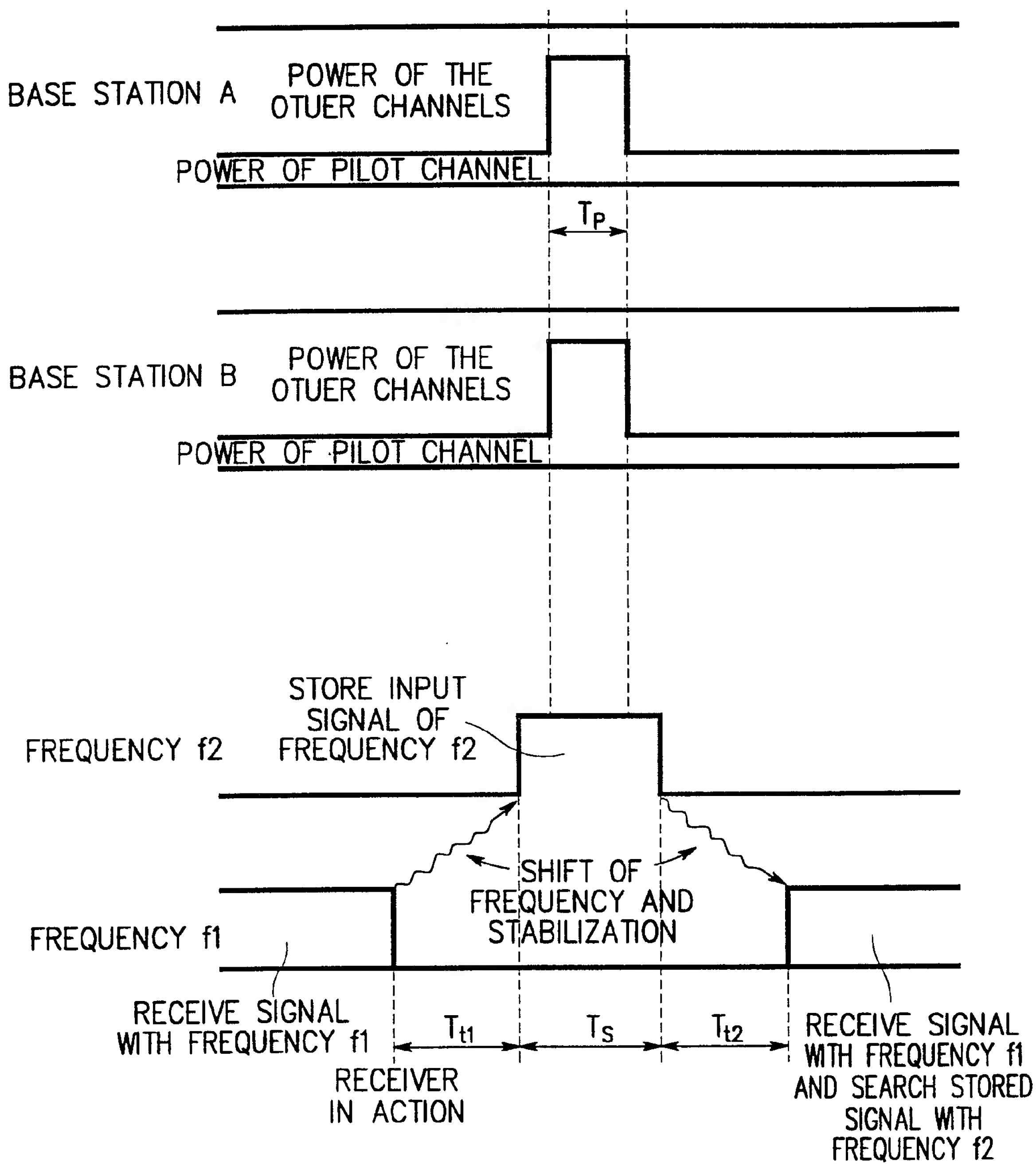
BASE STATION A
POWER OF THE OTUER CHANNELS
POWER OF PILOT CHANNEL
T_P
BASE STATION B
POWER OF THE OTUER CHANNELS
POWER OF PILOT CHANNEL
STORE INPUT SIGNAL OF FREQUENCY f2
FREQUENCY f2
SHIFT OF FREQUENCY AND STABILIZATION
FREQUENCY f1
RECEIVE SIGNAL WITH FREQUENCY f1
T_{t1}
T_S
T_{t2}
RECEIVER IN ACTION
RECEIVE SIGNAL WITH FREQUENCY f1 AND SEARCH STORED SIGNAL WITH FREQUENCY f2

FIG. 18

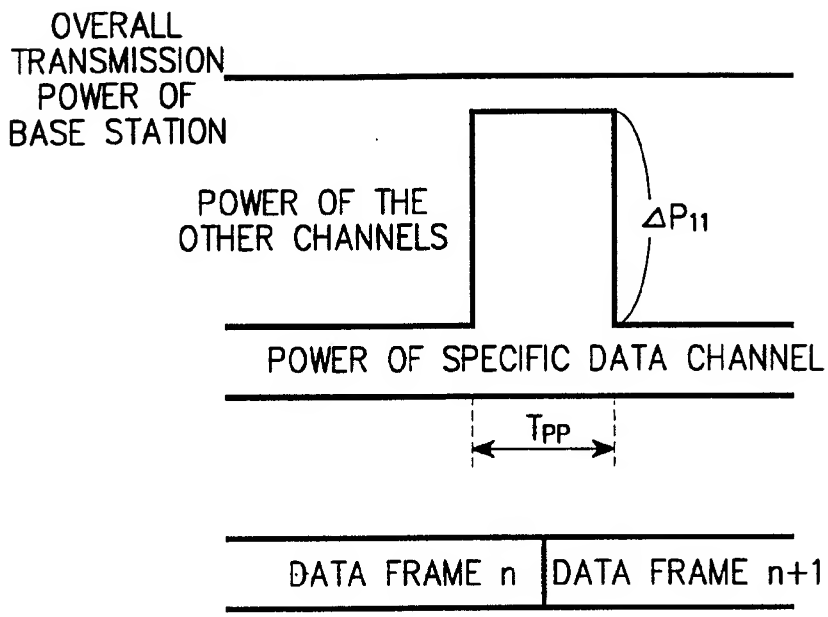

FIG. 19A

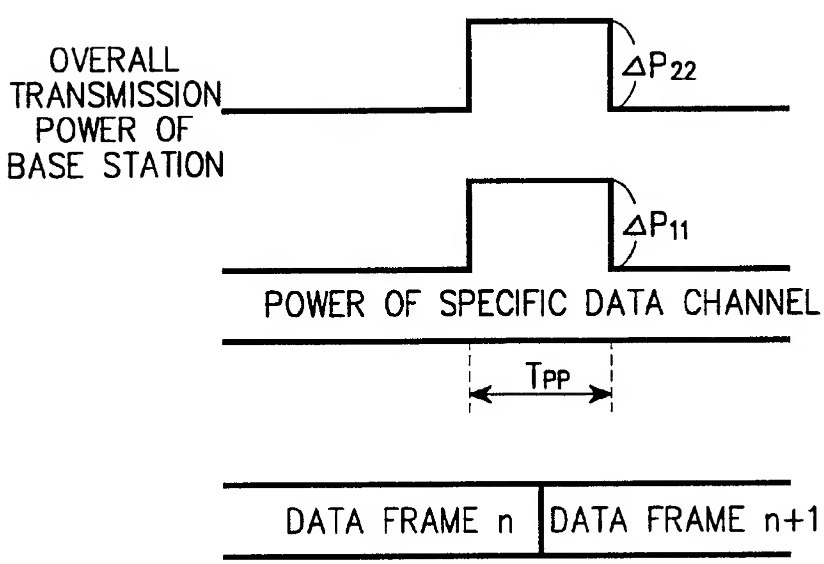

FIG. 19B

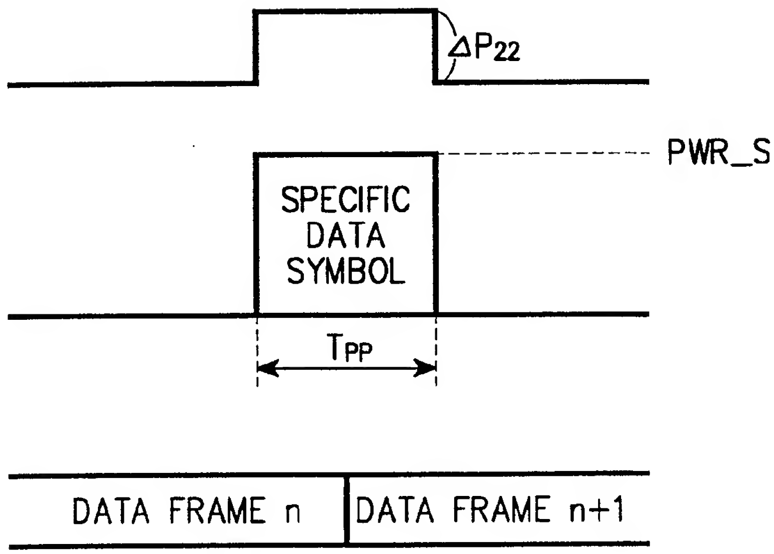

FIG. 19C

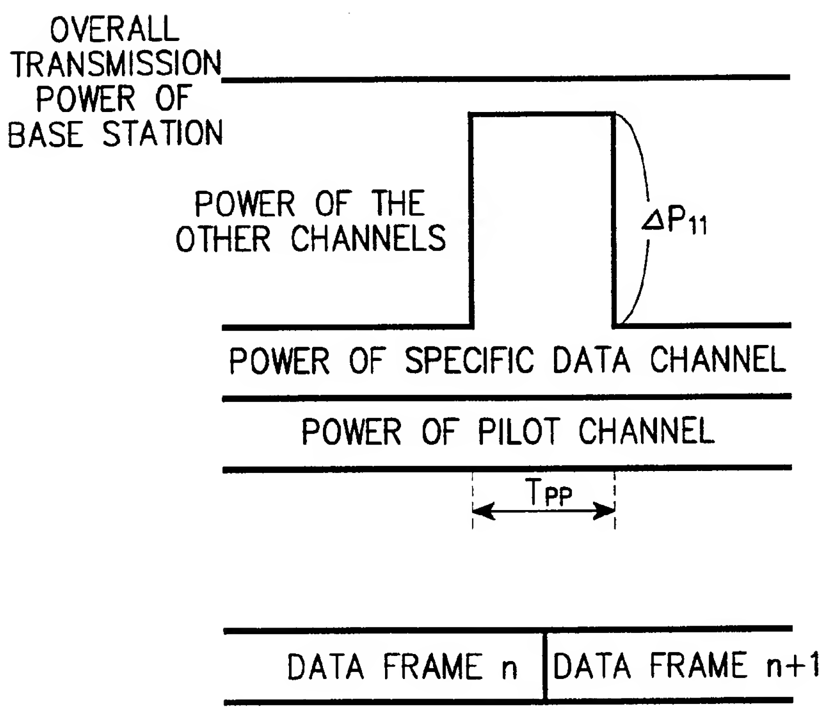

FIG. 19D

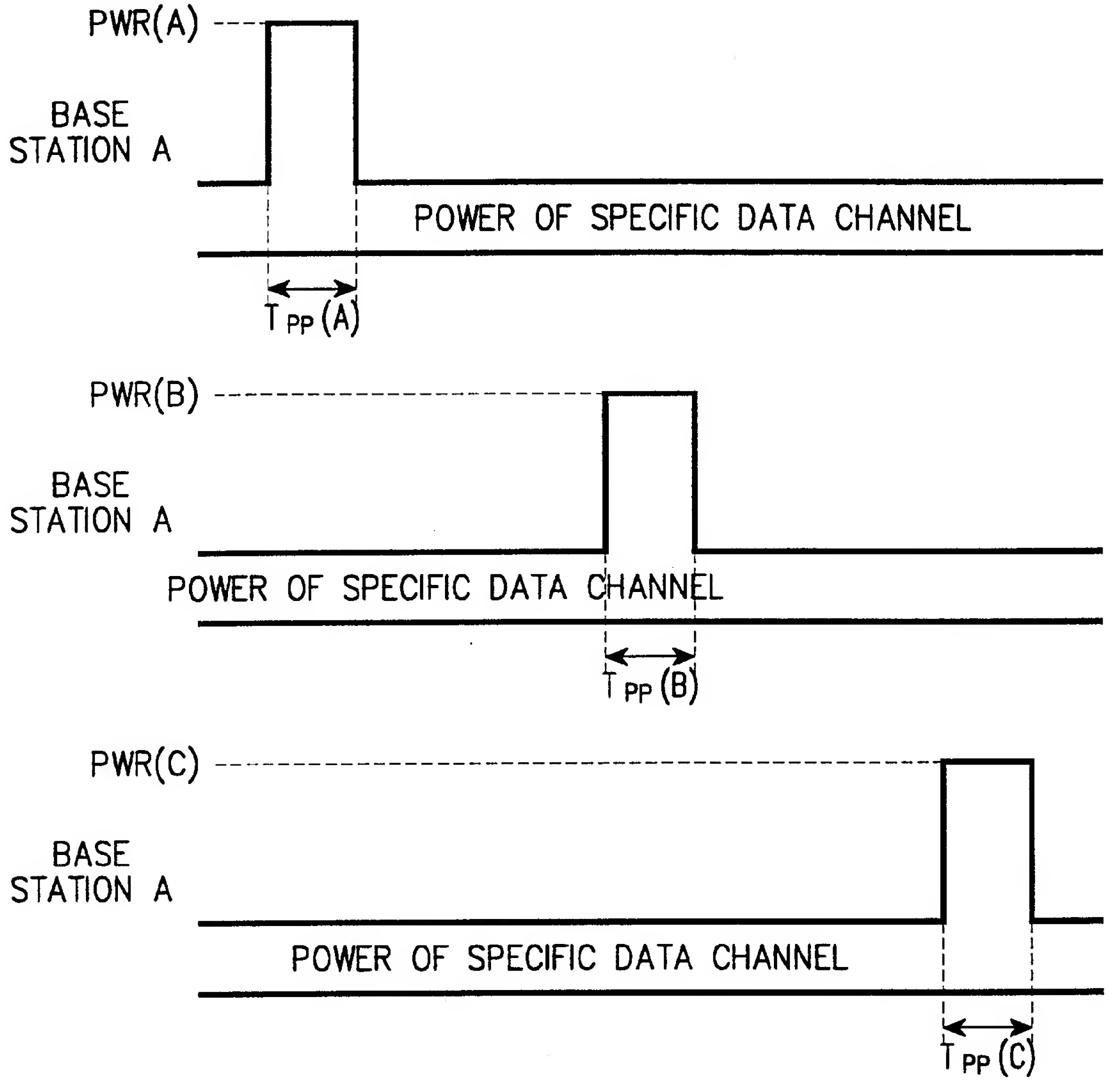
PWR(A)
BASE STATION A
POWER OF SPECIFIC DATA CHANNEL
T PP (A)
PWR(B)
BASE STATION A
POWER OF SPECIFIC DATA CHANNEL
T PP (B)
PWR(C)
BASE STATION A
POWER OF SPECIFIC DATA CHANNEL
T PP (C)

FIG. 20A

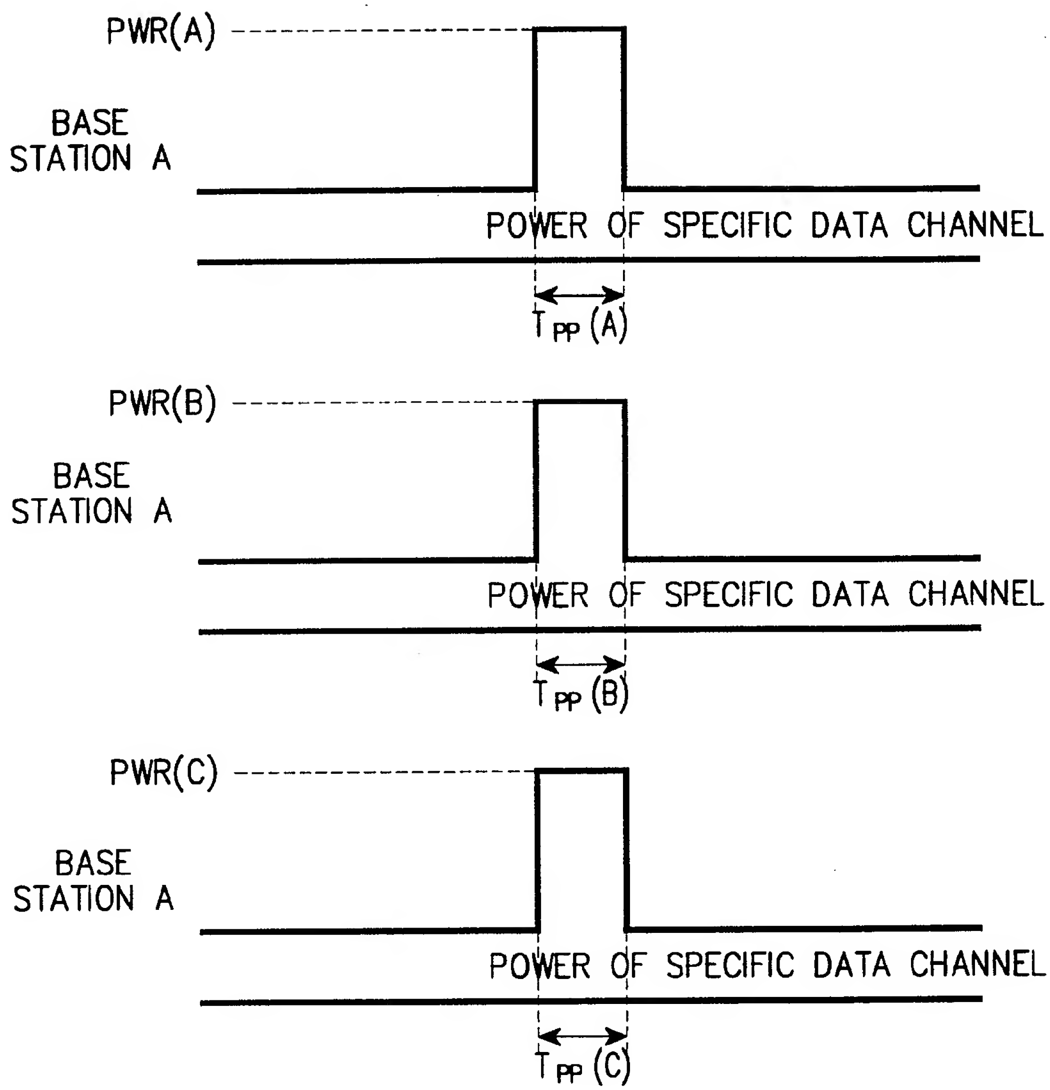
PWR(A)
BASE
STATION A
POWER OF SPECIFIC DATA CHANNEL
T_{PP} (A)
PWR(B)
BASE
STATION A
POWER OF SPECIFIC DATA CHANNEL
T_{PP} (B)
PWR(C)
BASE
STATION A
POWER OF SPECIFIC DATA CHANNEL
T_{PP} (C)

FIG. 20B

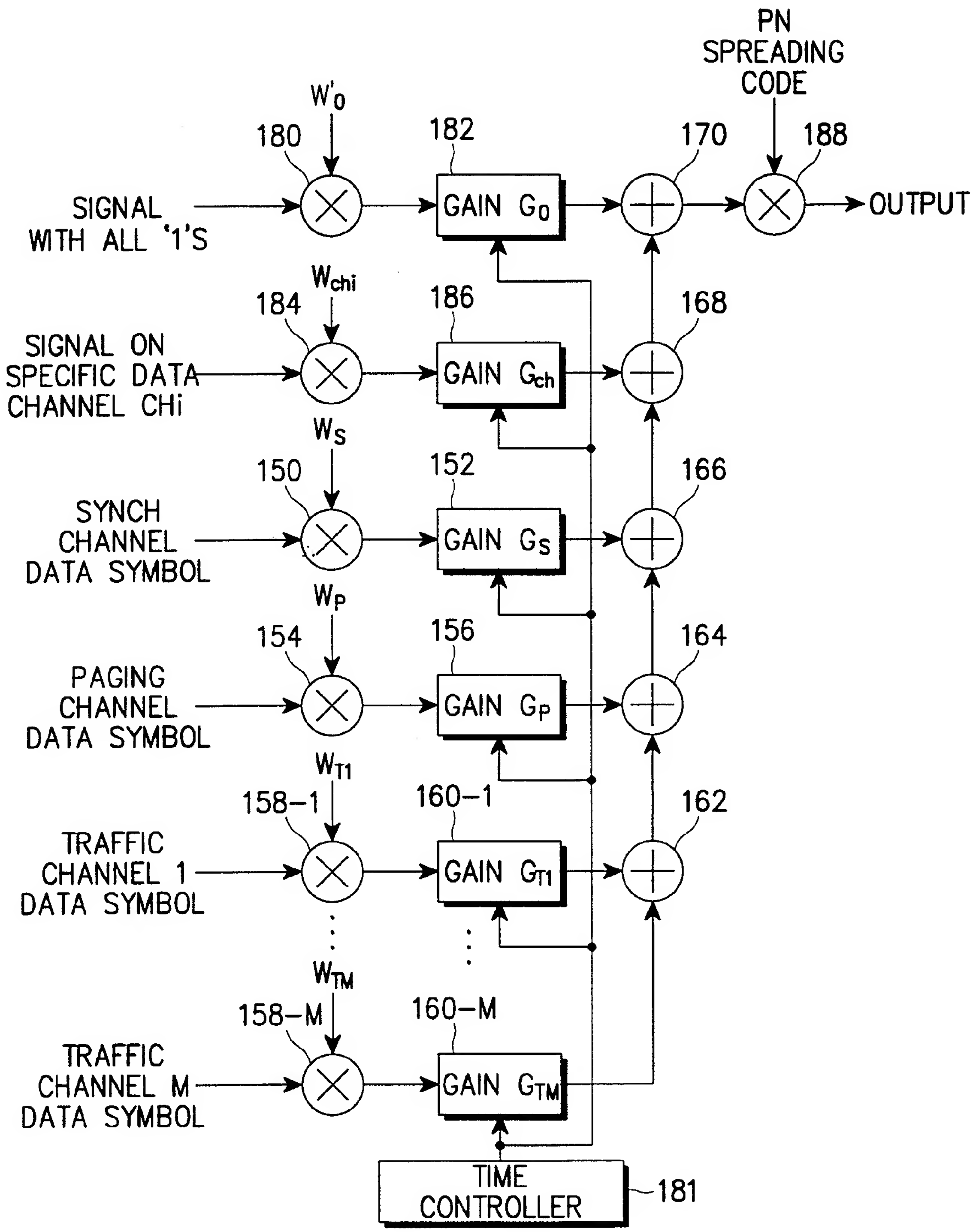
PN SPREADING CODE
W'0
180
182
170
188
SIGNAL WITH ALL '1'S
GAIN G0
OUTPUT
Wchi
184
186
168
SIGNAL ON SPECIFIC DATA CHANNEL CHi
GAIN Gch
WS
150
152
166
SYNCH CHANNEL DATA SYMBOL
GAIN GS
WP
154
156
164
PAGING CHANNEL DATA SYMBOL
GAIN GP
WT1
158-1
160-1
162
TRAFFIC CHANNEL 1 DATA SYMBOL
GAIN GT1
WTM
158-M
160-M
TRAFFIC CHANNEL M DATA SYMBOL
GAIN GTM
TIME CONTROLLER
181

FIG. 21

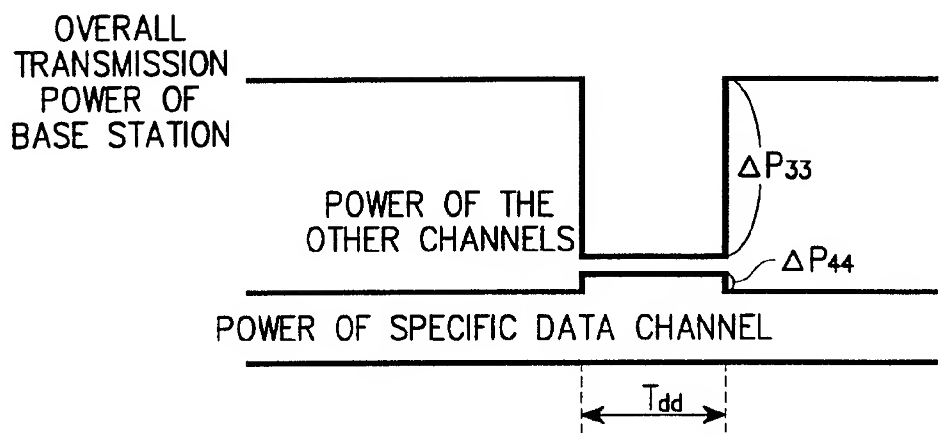
OVERALL TRANSMISSION POWER OF BASE STATION
POWER OF THE OTHER CHANNELS
ΔP33
ΔP44
POWER OF SPECIFIC DATA CHANNEL
Tdd

FIG. 22

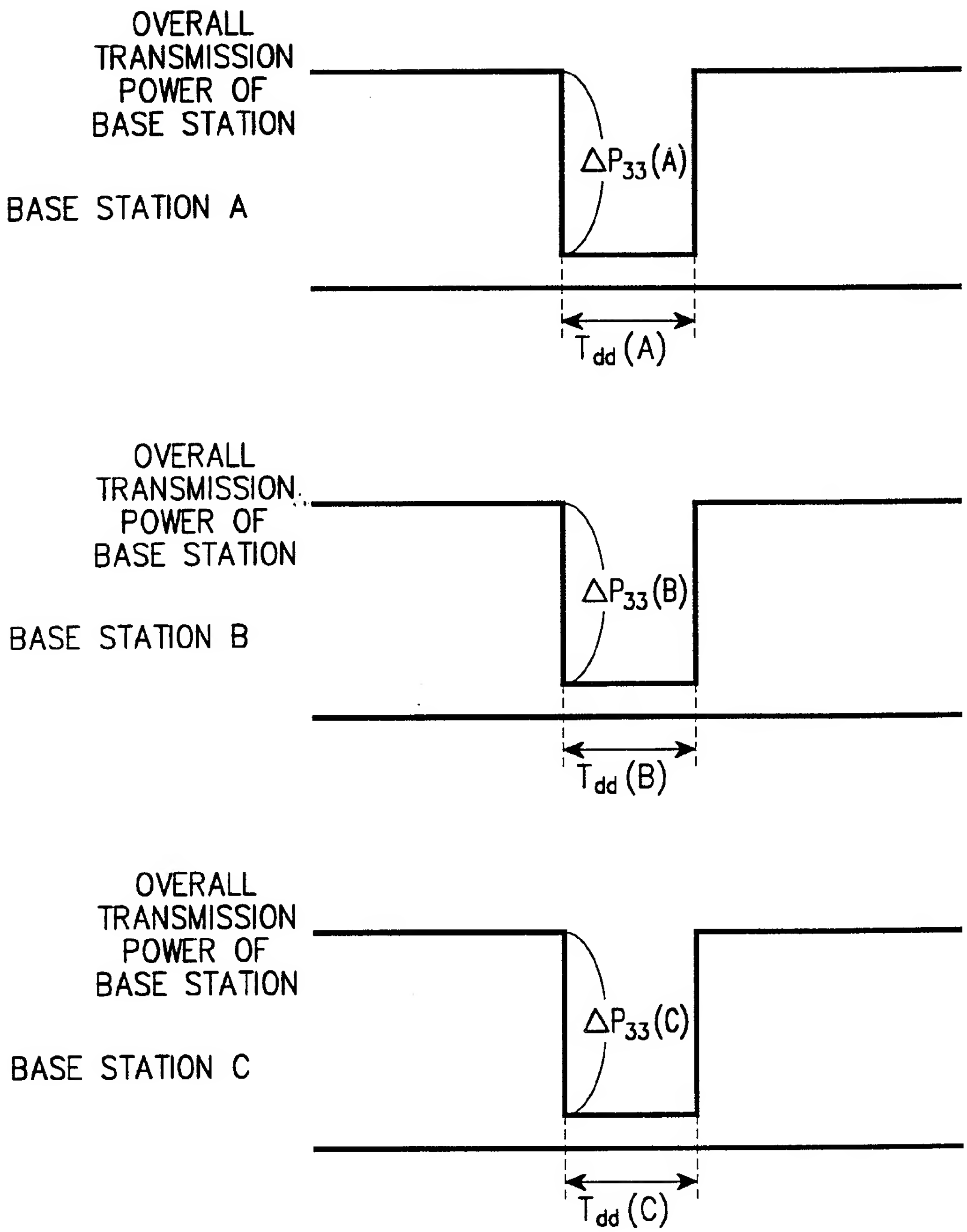
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION A
$\Delta P_{33}(A)$
$T_{dd}(A)$
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION B
$\Delta P_{33}(B)$
$T_{dd}(B)$
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION C
$\Delta P_{33}(C)$
$T_{dd}(C)$

FIG. 23A

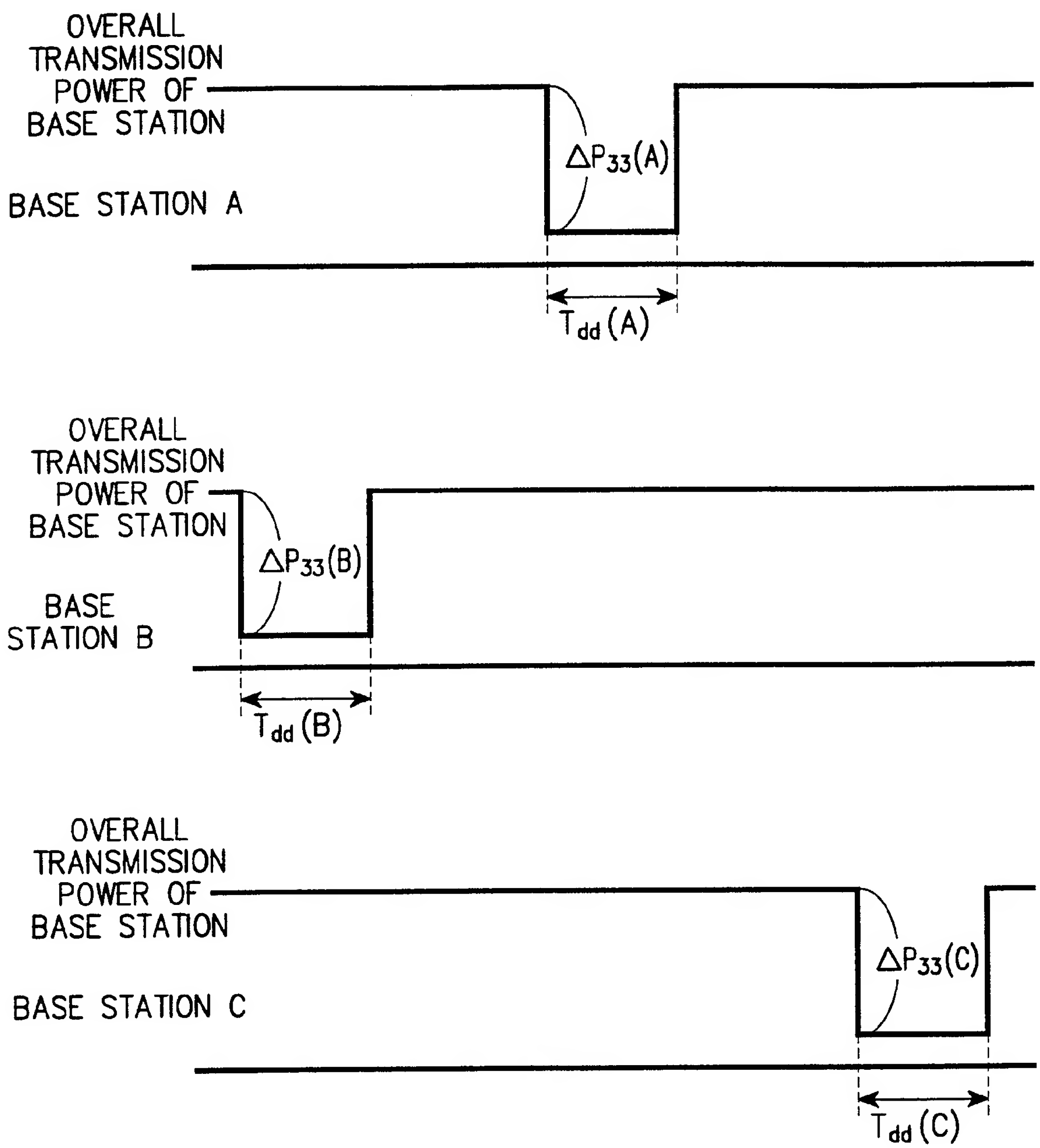
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION A
ΔP33(A)
Tdd (A)
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION B
ΔP33(B)
Tdd (B)
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION C
ΔP33(C)
Tdd (C)

FIG. 23B

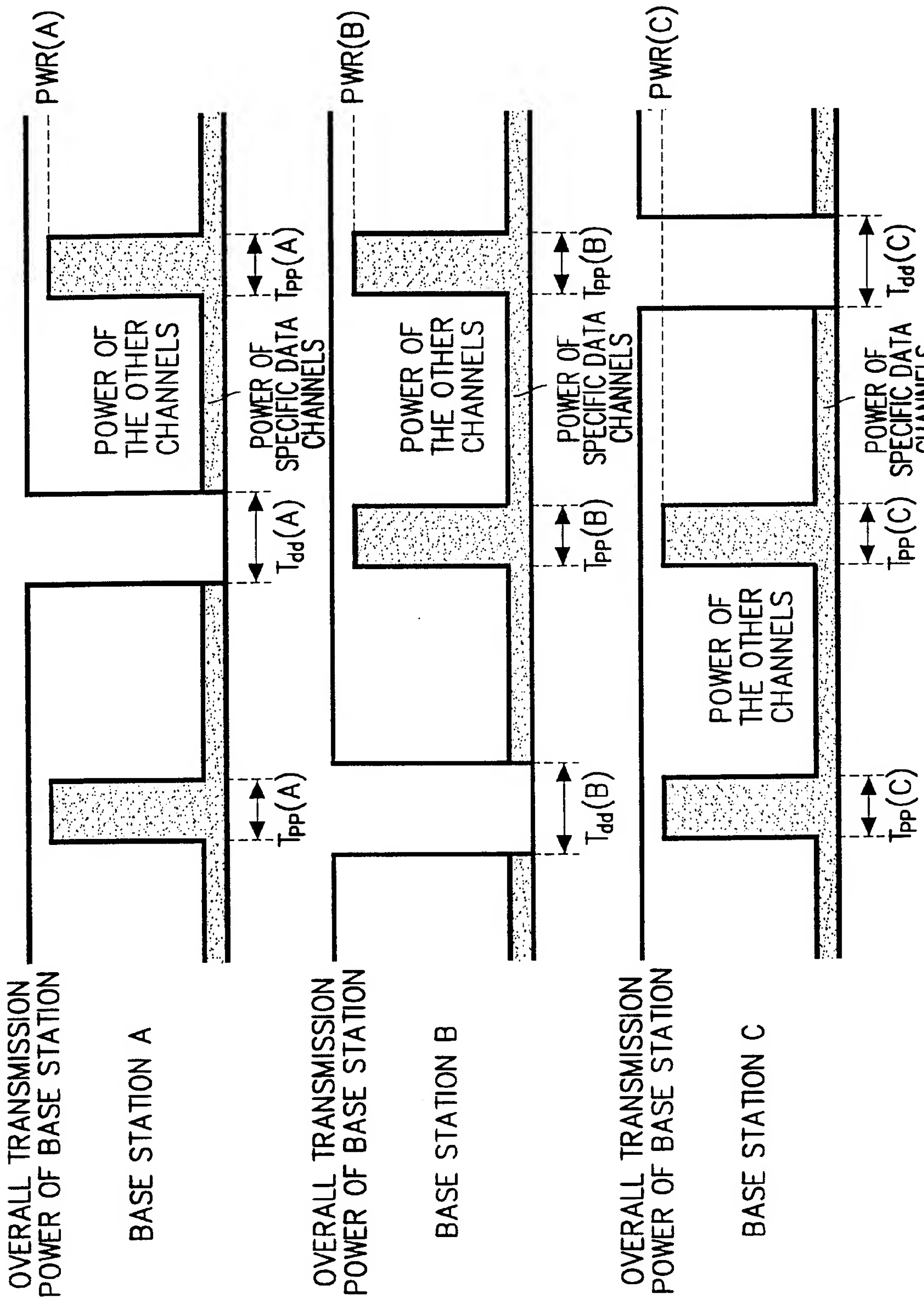
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION A
PWR(A)
POWER OF THE OTHER CHANNELS
POWER OF SPECIFIC DATA CHANNELS
$T_{PP}(A)$
$T_{dd}(A)$
$T_{PP}(A)$
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION B
PWR(B)
POWER OF THE OTHER CHANNELS
POWER OF SPECIFIC DATA CHANNELS
$T_{PP}(B)$
$T_{PP}(B)$
$T_{dd}(B)$
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION C
PWR(C)
$T_{dd}(C)$
POWER OF SPECIFIC DATA CHANNELS
$T_{PP}(C)$
POWER OF THE OTHER CHANNELS
$T_{PP}(C)$

FIG. 24A

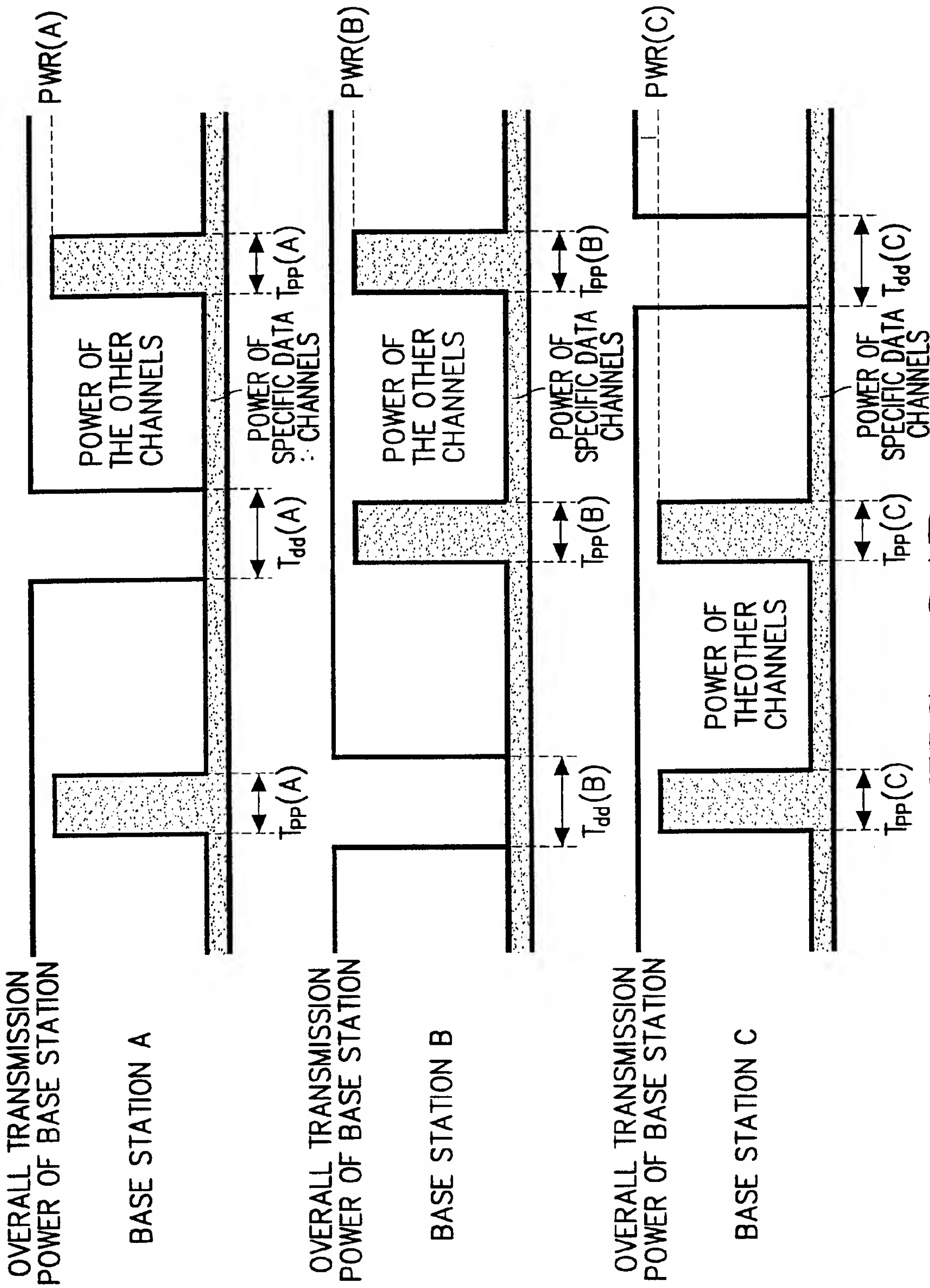
PWR(A)
POWER OF THE OTHER CHANNELS
POWER OF SPECIFIC DATA : CHANNELS
$T_{PP}(A)$
$T_{dd}(A)$
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION A
PWR(B)
POWER OF THE OTHER CHANNELS
POWER OF SPECIFIC DATA CHANNELS
$T_{PP}(B)$
$T_{dd}(B)$
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION B
PWR(C)
POWER OF THEOTHER CHANNELS
POWER OF SPECIFIC DATA CHANNELS
$T_{dd}(C)$
$T_{PP}(C)$
OVERALL TRANSMISSION POWER OF BASE STATION
BASE STATION C

FIG. 24B

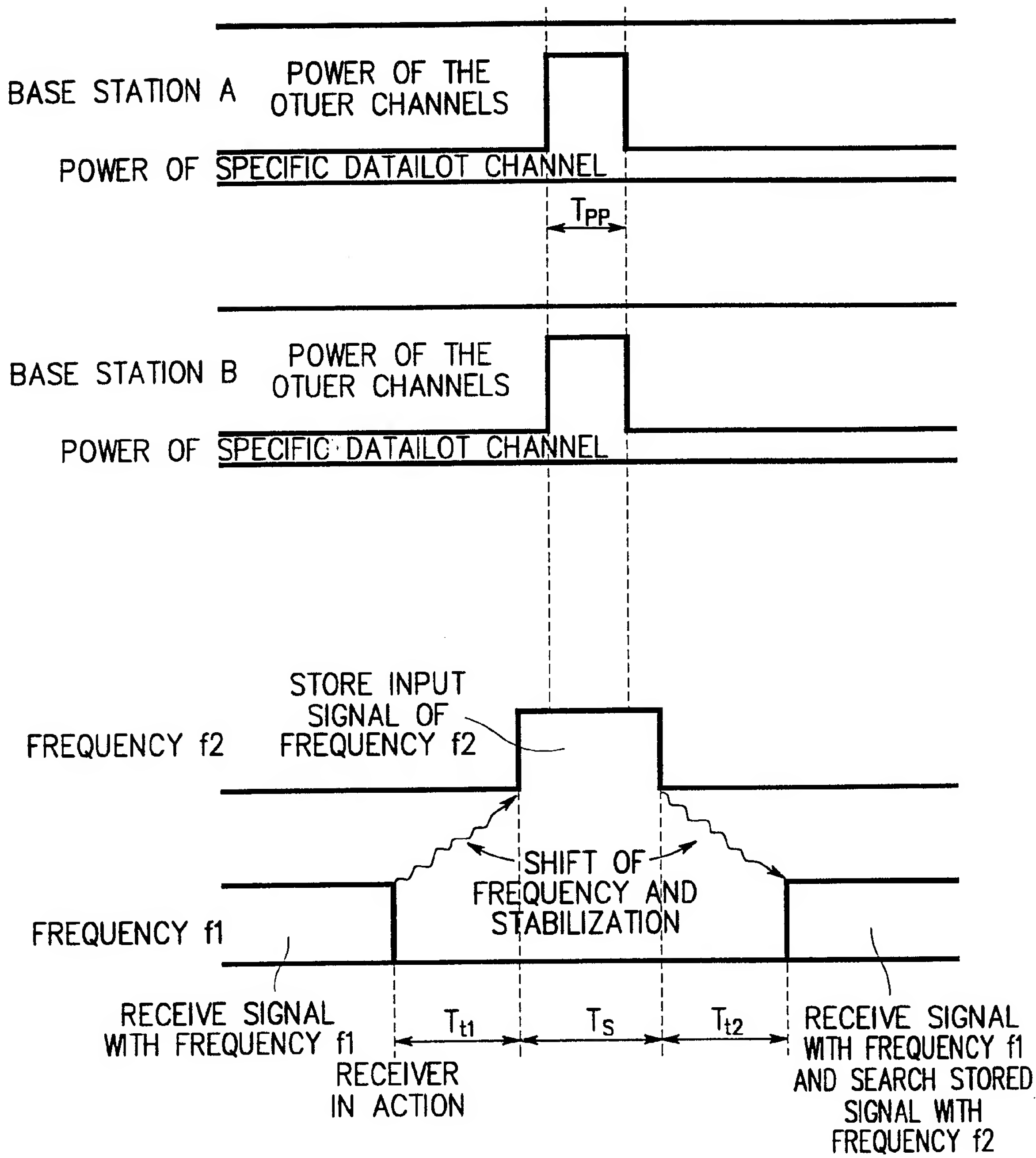
BASE STATION A
POWER OF THE OTUER CHANNELS
POWER OF SPECIFIC DATAILOT CHANNEL
T_{PP}
BASE STATION B
POWER OF THE OTUER CHANNELS
POWER OF SPECIFIC DATAILOT CHANNEL
STORE INPUT SIGNAL OF FREQUENCY f2
FREQUENCY f2
SHIFT OF FREQUENCY AND STABILIZATION
FREQUENCY f1
RECEIVE SIGNAL WITH FREQUENCY f1
T_{t1}
T_S
T_{t2}
RECEIVER IN ACTION
RECEIVE SIGNAL WITH FREQUENCY f1 AND SEARCH STORED SIGNAL WITH FREQUENCY f2

FIG. 25

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(72) Inventors: **HOTTINEN, Ari** [FI/FI]; Ristiniementie 4 o 30, FIN-02320 Espoo (FI). **TEITTINEN, Marko** [FI/FI]; Baueracher 22 C, D-44627 Herne (DE). **SUNAY, M., Oguz** [TR/US]; 123 Summit Avenue, Number 5, Summit, NJ 07901 (US).

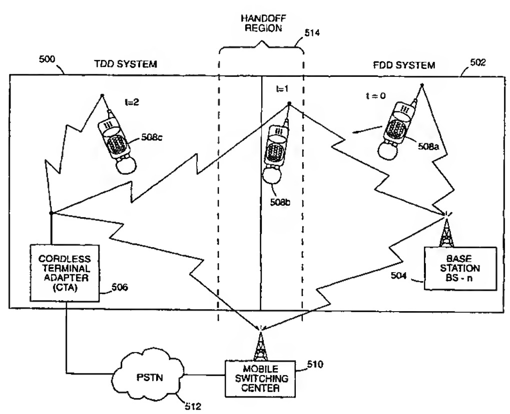
(74) Agent: **FUNK, Steven, R.**; Altera Law Group, LLC, 10749 Bren Road East, Opus 2, Minneapolis, MN 55343 (US).

(81) **Designated States** *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

(54) **Title:** SYSTEM AND METHOD FOR PERFORMING SOFT HANDOFF BETWEEN FREQUENCY DIVISION DUPLEX AND TIME DIVISION DUPLEX COMMUNICATION SYSTEMS



(57) **Abstract:** A system and method for controlling information transmission and communication handoff between frequency division multiplexing (FDD) and time division multiplexing (TDD) communication systems using any multiple access scheme is provided. The mobile unit transmits information via a current one of the FDD and TDD communication systems while it moves toward the other, or targeted one of the FDD and TDD communication systems. A pilot search signal is generated by the targeted communication system, where the pilot search signal corresponds to a transmission range of the targeted communication system. A communication handoff is initiated from the current communication system to the targeted communication system when the mobile unit recognizes a predetermined threshold level of the pilot search signal. Concurrent communications are synchronized and temporarily maintained between the mobile unit and both the current and targeted communications systems using an increased data rate for each of the communications links. When the handoff is complete, transmission between the mobile unit and the current communication system is terminated, while communication between the mobile unit and the targeted communication system is maintained when the handoff is complete.

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SYSTEM AND METHOD FOR PERFORMING SOFT HANDOFF BETWEEN FREQUENCY DIVISION DUPLEX AND TIME DIVISION DUPLEX COMMUNICATION SYSTEMS

FIELD OF THE INVENTION

The present invention relates generally to communications systems. More particularly, this invention relates to a system and method for controlling information transmission and communication handoff between frequency division multiplexing and time division multiplexing communication systems using any multiple access scheme.

BACKGROUND OF THE INVENTION

The modern communications era has brought about a tremendous proliferation of wireline and wireless networks. Computer networks, television networks, and telephony networks in particular are experiencing an unprecedented technological expansion, fueled by consumer demand. The ever-increasing need for transportation, due in part to the expansion of the world-wide market and the popularity of suburbia, has led to an increased use of automobiles and airplanes for business and pleasure. The desire to maintain the ability to communicate, even while away from the home or office, has driven the wireless communication market to a large extent. One response to this demand was the mobile/wireless telephone network.

The demand by consumers all over the world for mobile communications is expanding at a rapid pace and will continue to do so for at least the next decade. Over 100 million people were using a mobile service by the end of 1995, and that number is expected to grow to 300 million by the year 2000. Several factors are contributing to the exciting growth in the telecommunications industry. For example, a combination of technology and competition bring more value to consumers. Phones are smaller, lighter, have a longer battery life, and are affordable now for the mass market. Operators are providing excellent voice quality, innovative services, and roaming across the country or world. Most important, mobility is becoming less expensive for people to use. Around the world, as well as in the United States, governments are licensing additional spectrum for new operators to compete with traditional cellular operators. Competition brings innovation, new services, and lower prices for consumers.

Cellular telephone communications systems allow users of cellular telephones to be connected to other cellular telephone users, as well as being connected to the conventional landline Public Switched Telephone Network (PSTN). Cellular telephones work by dividing geographical areas into “cells”. Each cell includes a base station, which typically contains a transceiver, antenna, and dedicated lines to a Mobile Telephone Switching Office (MTSO). Adjacent cells may utilize different radio frequencies in order to prevent interference between the adjacent cells.

In TDMA or FDMA systems it is customary that each cell has at least one setup channel dedicated to signaling between the cell and cellular units within each cell, while the remaining channels are used for conversation. Each frequency channel may be re-used between cells, as long as the re-used channels are not in adjacent cells, and are far enough apart to avoid excessive interference. A network with a relatively small number of subscribers can therefore use large cells, and as demand grows, the cells may be divided into smaller cells.

Accordingly, in cellular networks, calls have to be passed as the vehicle or mobile unit moves from one cell to another. This is referred to as “handoff” or “handover”. As a vehicle moves away from a base station, its signal strength decreases. While handoff is often implemented in mobile systems because of mobility of the users, there are other reasons for implementing a handoff. For example, a stationary terminal may perform a handoff to utilize a different resource where the alternative resource is preferred, such as in the case of an imbalance in the system load, better efficiency in the alternative resource, signal quality, ownership of resources, forced handoff, and the like.

The base station monitors the signal strength during the duration of the call. When signal strength falls below a predetermined threshold level, the network makes a request to all predetermined neighboring cells to report the signal strength of the mobile station in the vehicle. If the signal strength in the neighboring cell is stronger by a

predetermined amount, then the network attempts to handoff the call to the neighboring cell.

The manner in which handoff occurs, and the relative quality of the handoff, depends largely on the channel access method utilized. These access methods are used to increase the traffic-carrying capacity and to provide access to that capacity. Many different access methods have been employed, including Frequency Division Multiple Access (FDMA), which divides the capacity into multiple frequency segments between end points. Time Division Multiple Access (TDMA) is another access method, which uses the concept of time sharing the total capacity. Still another access method is Code Division Multiple Access (CDMA), which may be based on the IS-95 industry specification. IS-95 CDMA combines new digital spread spectrum CDMA and advanced mobile phone service (AMPS) functionality into one dual-mode cellular telephone on the 800 MHz band, and can use a CDMA-only handset on the 1.9 GHz PCS band.

CDMA systems primarily differ from FDMA (Analog) and TDMA systems through the use of coded radio channels. In a CDMA system, users can operate on the same radio channel simultaneously by using different coded sequences.

IS-95 CDMA cellular systems have several key attributes that are different from other cellular systems. The same CDMA radio carrier frequencies may be optionally used in adjacent cell sites, which eliminates the need for frequency planning.

In AMPS cellular systems, handoff occurs when the base station detects a deterioration in signal strength from the mobile station. As AMPS subscribers approach handoff, signal strength may vary abruptly and the voice is muted for at least 200 milliseconds in order to send control messages and complete the handoff. In contrast, CDMA uses a unique soft handoff, which is nearly undetectable and loses few if any information frames. As a result, CDMA's soft handoff is much less likely to lose a call during handoff.

For providing duplex communication, transmission techniques such as Time Division Duplex (TDD) and Frequency Division Duplex (FDD) have been used. FDD provides for forward link (downlink) and reverse link (uplink) channel communications in different frequency bands. In TDD, a single channel is shared in time to carry both the transmit and receive information virtually simultaneously to achieve full duplex operation. Typically, FDD is used in outdoor systems, and TDD is used in indoor systems, or whenever local coverage is needed, due to the slow varying nature of the propagation channel and channel reciprocity.

TDD and FDD are currently not utilized in the same system. As previously described, CDMA systems, for example, use a "soft handoff", which is a call state where two or more base stations support a mobile station. This, however, differs from a handoff between a TDD and an FDD system. In future systems, TDD and FDD may be optional features of one system. Therefore, there is a need to support handoffs between TDD and

FDD systems in a wireless environment. The present invention provides for seamless handoff between TDD and FDD systems, and offers other advantages over the prior art.

SUMMARY OF THE INVENTION

The present invention is directed to a system and method for controlling communication handoff between frequency division multiplexing and time division multiplexing communication systems using any multiple access scheme.

In accordance with one embodiment of the invention, a method for controlling mobile unit communication handoffs between a frequency division duplex (FDD) communication system and a time division duplex (TDD) communications system is provided. The mobile unit transmits information via a current one of the FDD and TDD communication systems while it moves toward the other, or targeted one of the FDD and TDD communication systems. A pilot search signal or any other cell identification signal is generated by the targeted communication system, where the pilot search signal corresponds to a transmission range of the targeted communication system. A communication handoff is initiated from the current communication system to the targeted communication system when the mobile unit recognizes a predetermined threshold level of the pilot search signal. Concurrent communications are synchronized between the mobile unit and both the current and targeted communications systems. When the handoff is complete, transmission between the mobile unit and the current communication system is terminated, while communication between the mobile unit and the targeted communication system is maintained when the handoff is complete.

In accordance with another embodiment of the invention, the synchronization includes an initial synchronization of the handoff, and further includes temporary operation in a multirate mode. The initial synchronization includes increasing the data rate during an uplink frame with the system currently in operation, while transmitting a synchronizing preamble to the targeted communication system in the remaining uplink frame time which was made available by the increased data transfer rate with the current communication system. Communications enters the multirate mode upon acknowledgment of the synchronization by the targeted communication system. The multirate mode includes communicating the information with the current communication system at an increased data rate in the uplink frame, and concurrently communicating the information with the targeted communication system at an increased data rate in a remaining portion of each uplink frame.

In accordance with another aspect of the invention, a system for managing mobile unit communication handoffs between a frequency division duplex (FDD) communication system and a time division duplex (TDD) communication system is provided. An FDD base station is provided within the FDD communication system for communicating with the mobile unit in frequency division duplex mode, and for generating a pilot search signal corresponding to a transmission range of the FDD communication system. A TDD base station is provided within the TDD communication system for communicating with the mobile unit in time division duplex mode,

and for generating a pilot search signal corresponding to a transmission range of the TDD communication system. A mobile unit transmits information via a current one of the FDD and TDD communication systems while moving towards the other, or targeted one of the FDD and TDD communication systems. The mobile unit includes a receiving unit to receive the first and second pilot search signals, and to initiate a handoff from the current communication system to the targeted communication system when the pilot search signal from the targeted communication system has reached a predetermined threshold level. The mobile unit further includes a dual-transceiver to synchronize concurrent communications between the mobile unit and the current and targeted communication systems, and to concurrently communicate the information with the current communication system and the targeted communication system upon synchronization. The dual-transceiver includes a burst mode capable of increasing a data rate between the mobile unit and the current and targeted communication systems during the handoff to concurrently support communication with both the current and targeted communications systems.

In accordance with another aspect of the invention, a method for maintaining a connection between a frequency division duplex (FDD) communication system and a time division duplex (TDD) communication system during handoff of a communication unit from one communication system to the other is provided. The method includes transmitting a first portion of a communication frame to one of the FDD and TDD

communication systems, and transmitting a second portion of the communication frame to the other one of the FDD and TDD communication systems. At least one of the first and second portions of the communication frame is transmitted at an increased data rate. The communication occurs with both the FDD and TDD systems during the transmission of the communication frame, and the communication occurs in a time equivalent to the time required to transmit the communication frame to either of the FDD and TDD systems when no handoff is occurring.

In accordance with yet another embodiment of the invention, a method is provided for controlling information transmissions between a communications unit and both frequency division duplex (FDD) and time division duplex (TDD) communication systems. The communication unit is transmitting information via a first one of the FDD and TDD communication systems, and a cell identification signal is generated which corresponds to a transmission range of the other one of the FDD and TDD communication systems. Substantially simultaneous communication is initiated between the communications unit and both the FDD and TDD communications systems when the communications unit acknowledges the cell identification signal and is thereby in the coverage area of both the FDD and TDD communications systems. The substantially simultaneous communication between the communications unit and each of the FDD and TDD communications systems is maintained by simultaneously communicating at

least a part of the information with each of the FDD and TDD communications systems.

The above summary of the present invention is not intended to describe each illustrated embodiment or implementation of the present invention. This is the purpose of the figures and the associated discussion which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

Other aspects and advantages of the present invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 is a diagram depicting a multiple access cell network utilizing frequency division duplex (FDD) multiple accessing;

FIG. 2 illustrates the frequency characteristics of an FDD-paired frequency band;

FIG. 3 illustrates one possible time division duplex (TDD) configuration where "n" frequency channels provide for time division duplex communication;

FIG. 4 is a diagram illustrating an example of a time division duplex information transfer between two TDD systems;

FIG. 5 is a diagram illustrating one embodiment of a duplex-to-duplex handoff as a mobile station moves from an FDD system to a TDD system;

FIG. 6 is a flow diagram of one embodiment of a handoff procedure between a system supported by an FDD protocol and a system supported by a TDD protocol;

FIG. 7 is a flow diagram of one embodiment of a soft handoff setup in accordance with the present invention;

FIG. 8 is a flow diagram of an example of an FDD-to-TDD synchronization in accordance with the present invention; and

FIGS. 9A and 9B illustrate one embodiment of the synchronization and multirate operation implemented during a duplex-to-duplex handoff.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

In the following description of the exemplary embodiments, reference is made to the accompanying drawings which form a part hereof; and in which is shown by way of illustration the specific embodiment in which the invention may be practiced. It is to be understood that other embodiments may be utilized, as structural changes may be made without departing from the scope of the invention.

The present invention provides a system and method for controlling information transmission and communication handoff between frequency division multiplexing and time division multiplexing communication systems using any multiple access scheme. This provides a means for a user of a mobile communications station to send and receive information to two systems, where one system utilizes frequency division duplex and the other utilizes time division duplex. The present invention therefore provides a means for operating under the control of a first of the duplex systems, synchronizing a handoff from the first to the second duplex system, temporarily communicating with both the first and second duplex systems during the handoff using increased data transfer rates, and finally maintaining operation with the second of the duplex systems.

Referring now to FIG. 1, a multiple access cell network **100** utilizing frequency division duplex (FDD) multiple accessing is illustrated. The illustrated cell network **100** includes a plurality of base stations (BS) labeled base station BS-A **102**, BS-B **104**, through base station BS-n **106**.

Each of the base stations in the cell network **100** implement FDD multiple access techniques. For example, base station BS-A **102** is shown having a plurality of frequency carriers labeled carrier-1 through carrier-n, wherein each of the carriers includes an FDD paired frequency bands shown as frequency band f_1 and f_2 on directional lines **108** and **110** respectively. The FDD system allows duplex operation using the two frequency bands f_1 and f_2. FDD multiple access cell networks such as the cell network **100** have typically been used in outdoor macro cell networks, and is a desirable technology for long range communications with lower bit rates.

Referring now to FIG. 2, the frequency characteristics of an FDD paired frequency band are shown. Each carrier band, such as carrier band A, includes a frequency range from which an FDD duplex communication occurs. The uplink frequency f_1 is represented by the frequency on line **200**, and the downlink frame takes place at a frequency f_2 represented by line **202**. The frequency range separating the uplink and downlink frequencies is shown as the duplex band **204**. Duplex communication is allowed by simultaneously providing communication uplink from the mobile station to the base station via frequency f_1, and downlink communication from the base station to the mobile station at frequency f_2.

In addition to the FDD multiple access protocol is the time division multiplex (TDD) wireless communication protocol. TDD allows for duplex communication in a single wireless communication channel using time division multiplexing techniques. FDD systems require two separate

frequencies in order to provide full duplex service, where one frequency transmits and one receives. TDD, on the other hand, allows a single channel to carry both the transmit and receive information virtually simultaneously.

Figure 3 illustrates one possible TDD configuration whereby "n" frequency channels provide for time division duplex communication. Frequency channel-1 **300** is illustrated as having an approximately 1.75 MHz frequency bandwidth, delineated by frequencies f_1 and f_2 on lines **302** and **304** respectively. Within the frequency channel-1 **300** is a transmit and receive path for information transfers on the common frequency channel. The transmit and receive information is transmitted at different timeslots to provide full duplex operation. Within each frequency channel, multiple information traffic channels can exist, whereby each traffic channel incorporates a TDD protocol.

Referring now to FIG. 4, a diagram illustrating an example of a time division duplex information transfer between two TDD systems is provided. As time passes during the information transfer, as depicted by line **400**, each of the TDD communication systems provides a series **402**, **404** of alternating transmit (TX) and receive (RCV) modes. For example, while one communication device is transmitting at TX **406**, another communication device is receiving the information at RCV **408**. This rapid toggling between the receive and transmit modes allows each of the systems to transmit at the same frequency. The communications devices

involved in the duplex communication synchronize to the timeslots created by this switching, so that one will be transmitting while the other is receiving.

The following description is directed to a mobile station handoff in a cellular network. However, the present invention is not limited to such handoffs, and is applicable for a communication handover between any FDD and TDD communication systems. For example, the present invention is also applicable to stationary systems where there is simultaneous communication in at least one duplex direction with both FDD and TDD systems. This may be desirable in certain situations, such as for load sharing purposes. The present invention is therefore applicable in cases of mobile station handoffs between FDD/TDD systems, or in stationary systems where the same information is simultaneously transmitted to/from both FDD/TDD systems for load sharing or other purposes. Therefore, while the present invention is particularly useful in the context of mobile station handoffs and is largely described in terms thereof, the present invention is not limited to mobile station handoffs.

Referring now to FIG. 5, a neighboring TDD system **500** and FDD system **502** are illustrated. The present invention relates to the implementation and control of information in a handoff between TDD and FDD systems, utilizing any multiple access scheme. While various multiple access schemes are possible, such as frequency division multiple access (FDMA), time division multiple access (TDMA) and code division multiple access (CDMA), the present invention is described, for purposes of

example, in the context of a CDMA system. However, the present invention is capable of operation with other multiple access systems, and therefore should not be limited to the CDMA systems described in the following embodiments.

The embodiment of FIG. 5 illustrates an FDD system **502** such as a CDMA/FDD system typically used in an outdoor wireless arrangement. The TDD system **500** of FIG. 5 represents a CDMA/TDD system used in a relatively short-range indoor wireless arrangement. The FDD system **502** may employ a number of carriers at every base station **504**, and when using each carrier it simultaneously occupies a first frequency f_1 for the information uplink, and a second frequency f_2 for the information downlink, as was described in connection with FIGS. 1 and 2. The TDD system **500**, on the other hand, typically provides for communication with a local base station, such as the cordless terminal adapter (CTA) **506**, at a common frequency F. It should be recognized that the FDD and TDD systems are not restricted to indoor-outdoor implementations. For example, TDD may be used in the same wireless cell site with FDD, but using a different frequency band.

A mobile station (MS) **508a** at time t=0 in the FDD system **502** communicates with other mobile stations, or with the mobile switching center (MSC) **510**, via the base station **504**. The MSC **510** provides an interface to other networks, such as the public switched telephone network (PSTN) **512**, integrated services digital networks (ISDN), and other data networks. As a user within the FDD system **502** moves closer to the TDD system **500**, the

MS **508b** enters a handoff region **514** at time t=1. The handoff region **514**, as will be described in further detail below, represents a region where support of an mobile station from one base station to another is transferred. As the MS **508c** moves out of the handoff region **514** and completely within the TDD system **500** at time t=2, the MS **508c** communicates via its supporting base station, illustrated as a local CTA **506**. The CTA **506** can be networked to the PSTN **512** directly, or can alternatively use wireless means to communicate via the MSC **510**.

Figure 6 is a flow diagram of one embodiment of a handoff procedure from a system supported by an FDD protocol to a system supported by a TDD protocol, as was described in connection with FIG. 5. A mobile station MS is supported **600** by FDD communication via a first base station BS in a first cell area. The mobile station therefore utilizes a pair of frequencies separated by a duplex band to perform duplex communications between the mobile station and the base station. Where the mobile station is stationary, or is not moving towards a second cell area as determined at block **602**, the first base station continues to support the mobile station. Where the mobile station is moving **602** towards the second cell area, it is determined **604** whether the mobile station is within range of the second base station. In one embodiment of the invention, the first base station is a CDMA/FDD base station, and the second base station is a CDMA/TDD base station.

When it has been determined **604** that the mobile station has not moved within the range of the second base station, the first base station continues to support the mobile station. However, where the mobile station has moved to a point so as to be within the reach of the second base station, a handoff setup procedure is initiated **606**. The handoff setup allows the mobile station to identify that it is within the handoff region, request a handoff, and receive acknowledgment to a handoff request. One embodiment of the handoff setup **606** is described in further detail in connection with FIG. 7.

The mobile station receives notification through a handoff request acknowledgment that a handoff will be permitted. The handoff is synchronized **608**, which includes properly timing the information transfer throughout the handoff procedure. Handoff synchronization **608** continues until it is determined **610** that the synchronization is complete, at which time the mobile station entirely performs **612** the TDD communication through the second base station in the second cell area.

In one embodiment of the invention, the first cell area is an outdoor CDMA/FDD system, and the second cell area is an indoor CDMA/TDD system. The handoff occurs as the mobile station user moves from the outdoor system towards the indoor system. It should be recognized that the FDD and TDD systems can be co-located. The present invention also analogously provides for a handoff from the TDD to an FDD system, as will be readily apparent to those skilled in the art from the

description provided herein. In order to minimize noise, distortion, and handoff failures, and to provide uninterrupted communication during handoff, a "soft" handoff is used. This is described in greater detail in connection with FIGS. 8 and 9.

Referring now to FIG. 7, a flow diagram of one embodiment of a soft handoff setup is provided. A soft handoff is initiated by generating a pilot search signal **700** at the base station at which the mobile station is approaching. For example, in the present invention, an indoor TDD cordless terminal adapter generates a pilot search signal to be monitored by an approaching mobile station. The pilot signal is a predetermined signal that is broadcast from the base station. A mobile station, configured to receive the predetermined signal, will recognize the predetermined signal when it is within the physical operating range of the broadcasting base station. The particular pilot search signal can distinguish itself from other pilot signals by using a signal of a particular phase or frequency which differs from the phase or frequency of the other pilot signals.

The mobile station monitors **702** for the pilot search signal. In one embodiment of the invention, the mobile station monitors for a pilot signal that is sufficiently high in power, or alternatively where the path loss is small. If the pilot signal does not exceed the power threshold, the mobile station continues to monitor **702** the pilot search signal. One embodiment of the invention involves the use of a designated frequency by the TDD system which is also known by the mobile station. The mobile station then monitors

for a pilot signal at this designated frequency. This monitoring may be accomplished using an additional receiver, or could be accomplished using time or frequency division multiplexing methods.

When the mobile station determines **704** that the pilot search signal has exceeded a predetermined power threshold, the mobile station requests **706** the handoff. The mobile station handoff request is sent **708** from the mobile station to the "new" base station via the base station currently supporting the mobile station. For example, where the mobile station is moving from an outdoor FDD system having an FDD base station towards an indoor TDD system having a TDD cordless terminal adapter (CTA), the request for handoff is sent to the TDD CTA from the FDD base station. The new base station (e.g., the TDD CTA) determines **710** whether or not to grant access to the new base station, based on desired parameters, such as load control. Generally, load control refers to the manner in which the communication system ensures quality connections for all users of the system. This can be performed in a variety of ways, including shifting some users to other frequencies or base stations, or restricting particular service options.

If the new base station does not recognize that the access parameters have been met, no handoff will be allowed, and the mobile station may again request **706** handoff. Otherwise, the TDD system base station acknowledges **712** the handoff request by way of an

acknowledgment signal back to the mobile station through the FDD base station.

Once the handoff has been initiated, the handoff is synchronized to properly time the handoff at both the TDD and FDD systems. FIG. 8 is a flow diagram which provides an example of an FDD-to-TDD synchronization in accordance with the present invention. The first part of the uplink frame is sent with an increased data rate to the base station associated with the FDD system. In one embodiment, increasing the data rate involves doubling the data rate between the mobile station to the FDD system base station, as shown at block **800**. The increased data rate allows the time that would normally be remaining to be used to provide a preamble to the TDD base station to initially synchronize a TDD data transfer, as seen at block **802**. The preamble includes information for facilitating initial synchronization, and is sent in the latter portion of the uplink frame from the mobile station to the base station in the TDD system. The TDD base station acknowledges **804** the synchronization by returning an acknowledgment signal to the mobile station via a control channel known by the TDD base station and the mobile station.

When the synchronization has been established, the mobile station operates **806** in a multirate mode, where the data is sent to both duplex systems at a rate sufficient to allow the information to be sent to both systems in a period corresponding to one data frame. By increasing the data transfer rates in this manner, the same amount of information can be

transmitted from the mobile station to each of the FDD/TDD systems as would be transmitted to either of the FDD/TDD systems individually when not in handoff mode. One example of such a multirate mode is illustrated and described in connection with FIG. 9B.

Until the handoff is complete, the mobile station will continue to operate **806** in the multirate mode. When it is determined **808** that the handoff is complete, the mobile station is completely supported **810** by the new base station, which is the TDD base station in the present example.

FIG. 9A illustrates one manner in which the handoff synchronization is initiated in accordance with the present invention. The information frame **900** is a group of X bits sent serially over a communication channel, and is shown between times t=1 and t=2, which is the normal time for one frame to be transmitted. In order to initiate the handoff procedure, the uplink frame (f_{FDD1} in this example) is transmitted at an increased data rate to the FDD base station. In one embodiment of the invention, the data rate is doubled, which is represented on line **902**. Line **902** approximately represents the transmission time for transmitting X bits during the uplink frame, which is approximately one-half of the time normally required to transmit a frame as depicted by line **900**. Doubling the data rate at this phase allows the X bits in the uplink frame to be transmitted in approximately half the time.

The latter portion of the frame **900** is filled with preamble information which is sent to the "new" base station (e.g., the TDD base

station in this example). The preamble includes information for facilitating initial synchronization, and is sent from the mobile station to the FDD base station. The preamble includes a synchronization field comprising a bit pattern, or training sequence, that is known to the receiver. This training sequence provides for initial synchronization with the new base station, and can assist in channel estimation and equalization. As seen by line **904**, the latter portion of the frame is used to provide this preamble to the TDD communication system. The new base station acknowledges the synchronization to the mobile unit via a control channel, as depicted by the acknowledge signal on line **906**.

Referring now to FIG. 9B, one embodiment of the multirate operation during duplex-to-duplex handoff is illustrated. The information frame **900** having a number X bits is depicted between times t=1 and t=2. Prior to handoff, an active mobile station communicates with its corresponding base station. For example, FIG. 9B shows that a mobile station may be communicating with a base station using an FDD protocol prior to handoff. This can be seen on lines **912** and **914**, where information is provided from the mobile station to the base station on an uplink frame at a first frequency f_{FDD1}, and where information is provided from the base station to the mobile station on a downlink frame at a second frequency f_{FDD2}. The pilot search signal is sent at a frequency f_{PILOT}, represented on line **916**, which is recognized by the mobile station when in proximity to the base station that is broadcasting the pilot search signal.

When the mobile station recognizes the pilot search signal and has established the initial synchronization as described in FIG. 9A, the mobile station will operate in multirate mode during the handoff. One example of the multirate mode is shown on lines **918**, **920** and **922** of FIG. 9B. The f_{FDD1} uplink frame on line **918**, having a number X bits, is provided to the FDD base station at approximately twice the rate as it was provided prior to handoff shown on line **912**. The f_{FDD2} downlink frame on line **920** optionally has an increased data rate, thereby transmitting the X bits in a time approximately half of the time required to transmit the information prior to handoff as shown on line **914**. The information is also transmitted in time division duplex at a frequency f_{TDD1}, as shown on line **922** which represents a frequency at which a time division duplexing protocol is used to communicate with the new base station. This is accomplished in a period of time corresponding to one half of one frame prior to the handoff; i.e., during the latter portion of the frame **900**, which results in a 4-fold increase in data rate of the data rate of the original FDD signal on line **912**. This is due to the reduced time allotted to transmit the data, and to the characteristics of TDD where both the uplink and downlink transmission occurs at a common frequency. When the handoff is complete, the information is transmitted via the new base station in the TDD system only, as shown on line **924**. At this time, the multirate mode is disabled so that the 2X transmit and receive bits are transmitted at frequency f_{TDD1} during the one frame time interval between time t=1 and t=2.

The establishment of the multirate mode, which provides for an increased transfer rate during handoff, can be realized using a data burst mode. A data burst mode refers to an increase of the data rate. For example, increasing the data rate is one manner in which the present invention creates a virtually simultaneous connection between the two duplex systems. By using the multirate mode described above, all of the bits are transmitted via the FDD system and the TDD system in the time period typically used only by the FDD system. Alternatively, a portion of the frame (i.e., less than all of the bits of the frame) can be sent in the f_{FDD1} uplink frame (**918** of FIG. 9B), and the remaining bits to a TDD system in the f_{TDD1} frame (**922** of FIG. 9B). In this case, the first portion (for example, half of the frame bits) are sent with the same rate as in FDD-only operation. However, the latter TDD portion is sent at double rate, since only half of the time is available to send the frame as compared to TDD-only operation.

The present invention therefore allows an established communication connection to be maintained with both the FDD and TDD communication systems during handoff. It is not necessary that the entire communication frame be sent to both the FDD and TDD communication systems. For example, a first half of the communication frame can be transmitted to the FDD system, and the second half of the communication frame can be transmitted to the TDD system. The FDD system can operate at its normal rate, and the TDD system can operate at double rate such that the entire communication frame is transmitted by the cooperative

aggregation of the FDD and TDD communication systems. In this example, the first half of the frame is sent only to the FDD system, and the second half is sent only to the TDD system, and the entire communication frame is recreated at the receiving end. Where such “subframes” are transmitted, different frequencies may be used to transmit selected groups of the subframes. For example, a first number of the subframes can be transmitted in a different frequency than the rest of the subframes. The frequency can be changed in accordance with a predetermined pattern (i.e., frequency hopping).

Alternatively, where the entire communication frame is to be sent to both the FDD and TDD communication systems, the data transfer rate must be further increased; e.g., double the rate with respect to the FDD communication system and quadruple the rate with respect to the TDD communication system.

The present invention is also applicable in non-handoff situations. For example, a terminal such as a mobile station (MS) may be relatively stationary, meaning that it is not being moved through a handoff region such as handoff region 514 of FIG. 5. Rather, the MS in this embodiment may be in use at a certain location, such as within the FDD system or within the TDD system. The invention is very beneficial for purposes other than FDD/TDD handoff, such as for load sharing between FDD and TDD systems.

In such a case, the present invention utilizes the previously-described techniques to effect simultaneous communication in at least one duplex direction between the MS and each of the FDD and TDD systems. For example, assume a terminal using a 4 MHz FDD downlink band can normally achieve a 1 Mbps data rate. By directing an additional 500 Kbps of data via the TDD system a total of 1.5 Mbps can be achieved.

The manner in which the information is divided between the FDD and TDD systems can be determined as the situation requires. For example, all of the data could be delivered via the TDD downlink while using the FDD uplink for control. This “control” includes control signals for transmission parameters, such as transmission rate control signals, power control signals, modulation control signals, and encoding control signals. This arrangement can be used to occasionally increase the downlink capacity, or alternatively could be used for load sharing purposes. Such use requires essentially simultaneous transmission/reception using both the TDD and FDD systems, and would utilize a multirate mode as previously described.

It should be recognized that the embodiments described above are illustrative, and not to be limited thereto. For example, as will be readily apparent to those skilled in the art from the foregoing description, a handoff from a TDD system to an FDD system can also be accomplished. A handoff would be initiated as a mobile station moves from the TDD system to the FDD system by monitoring the pilot search signal of the FDD system. When

the pilot search signal is at a sufficient level, the mobile station requests the handoff, which can be granted by the FDD system. The handoff is synchronized by increasing the data rate of the TDD uplink frame, and a preamble will be sent in the latter portion of the frame to the FDD system to establish frequency division duplex communication. The FDD base station will acknowledge this synchronization, at which time the mobile station begins operating in a multirate mode, where it communicates information with the TDD system and FDD system concurrently.

Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

CLAIMS

What is claimed is:

1. A method for controlling mobile unit communication handoffs between a frequency division duplex (FDD) communication system and a time division duplex (TDD) communications system, wherein the mobile unit is transmitting information via a current one of the FDD and TDD communication systems while moving towards the other, or targeted one of the FDD and TDD communication systems, the method comprising:

generating a pilot search signal corresponding to a transmission range of the targeted communication system;

initiating the communication handoff from the current communication system to the targeted communication system when the mobile unit recognizes a predetermined threshold level of the pilot search signal;

synchronizing concurrent communications between the mobile unit to both the current and targeted communications systems; and

terminating transmission between the mobile unit and the current communication system, and maintaining communication between the mobile unit and the targeted communication system when the synchronization is complete.

2. The method as in Claim 1, wherein the current communication system is the FDD communication system, and the targeted communication system is the TDD communication system.

3. The method as in Claim 1, wherein the current communication system is the TDD communication system, and the targeted communication system is the FDD communication system.

4. The method as in Claim 1, wherein initiating the communication handoff comprises requesting a handoff by the mobile unit when the mobile unit recognizes the predetermined threshold level of the pilot search signal.

5. The method as in Claim 4, wherein requesting a handoff by the mobile unit comprises notifying the current communication system of the handoff request, and providing the handoff request to the targeted communication system via the current communication system.

6. The method as in Claim 5, further comprising determining whether to grant access to the mobile unit at the targeted communication system based on predetermined parameters, and providing an acknowledge signal from the targeted communication system to the mobile unit via the current communication system when warranted by the predetermined parameters.

7. The method as in Claim 6, wherein determining whether to grant access to the mobile unit based on predetermined parameters comprises analyzing load control parameters.

8. The method as in Claim 1, wherein synchronizing concurrent communications between the mobile unit to both the current and targeted communications systems comprises:

increasing a data rate in an uplink frame between the mobile unit and the current communications system; and

transmitting a synchronizing preamble to the targeted communications system during a remaining portion of the uplink frame made available by the increased data rate.

9. The method as in Claim 8, wherein increasing the data rate comprises approximately doubling the data rate between the mobile unit and the current communications system.

10. The method as in Claim 8, further comprising acknowledging synchronization to the mobile unit by the targeted communication system.

11. The method as in Claim 10, wherein acknowledging synchronization comprises providing an acknowledge signal to the mobile unit via a control channel.

12. The method as in Claim 10, further comprising operating in a multirate mode upon the synchronization acknowledgment, wherein the multirate mode comprises transmitting the information to the current communication system at an increased data rate in the uplink frame between the mobile unit and the current communications system, and transmitting the information to the targeted communication system at an increased data rate in a remaining portion of the uplink frame between the mobile unit and the targeted communications system.

13. A method for controlling mobile unit communication handoffs from a frequency division duplex (FDD) communication system to a time division duplex (TDD) communications system, wherein the mobile unit is transmitting information via the FDD communications system, the method comprising:

generating a pilot search signal corresponding to a transmission range of the TDD communication system;

initiating the communication handoff from the FDD communication system to the TDD communication system when the mobile unit recognizes a predetermined threshold level of the pilot search signal;

synchronizing concurrent communications between the mobile unit to both the FDD and TDD communications systems;

transmitting the information in a multirate mode upon acknowledgment of the synchronization by the TDD communication system, including communicating the information with the FDD communication system at an increased FDD data rate in the uplink frame between the mobile unit and the FDD communications system, and communicating the information with the TDD communication system at an increased TDD data rate in a remaining portion of the uplink frame between the mobile unit and the TDD communications system; and

terminating transmission between the mobile unit and the FDD communication system and maintaining communication between the mobile unit and the TDD communication system when the synchronization is complete.

14. The method as in Claim 13, wherein synchronizing concurrent communications between the mobile unit to both the FDD and TDD communications systems comprises:

increasing the FDD data rate in an uplink frame between the mobile unit and the FDD communications system; and

transmitting a synchronizing preamble to the TDD communications system during a remaining portion of the uplink frame made available by the increased FDD data rate.

15. The method as in Claim 14, wherein increasing the FDD data rate during synchronization comprises approximately doubling the FDD transmit data rate between the mobile unit and the FDD communications system.

16. The method as in Claim 14, further comprising acknowledging synchronization to the mobile unit by the TDD communication system.

17. The method as in Claim 13, wherein communicating the information to the FDD communication system at an increased FDD data rate comprises transmitting the information at approximately double the FDD transmit data rate.

18. The method as in Claim 13, wherein communicating the information to the TDD communication system at an increased TDD data rate comprises transmitting the information at approximately quadruple the FDD transmit data rate.

19. The method as in Claim 13, wherein the information is communicated by the mobile unit using CDMA.

20. A method for controlling mobile unit communication handoffs from a time division duplex (TDD) communication system to a frequency division duplex (FDD) communications system, wherein the mobile unit is transmitting information via the TDD communications system, the method comprising:

generating a pilot search signal corresponding to a transmission range of the FDD communication system;

initiating the communication handoff from the TDD communication system to the FDD communication system when the mobile unit recognizes a predetermined threshold level of the pilot search signal;

synchronizing concurrent communications between the mobile unit to both the TDD and FDD communications systems;

transmitting the information in a multirate mode upon acknowledgment of the synchronization by the FDD communication system, including communicating the information with the TDD communication system at an increased TDD data rate in the uplink frame between the mobile unit and the TDD communications system, and communicating the information with the FDD communication system at an increased FDD data

rate in a remaining portion of the uplink frame between the mobile unit and the FDD communications system; and

terminating transmission between the mobile unit and the TDD communication system and maintaining communication between the mobile unit and the FDD communication system when the synchronization is complete.

21. The method as in Claim 20, wherein synchronizing concurrent communications between the mobile unit to both the TDD and FDD communications systems comprises:

increasing the TDD data rate in an uplink frame between the mobile unit and the TDD communications system; and

transmitting a synchronizing preamble to the FDD communications system during a remaining portion of the uplink frame made available by the increased TDD data rate.

22. The method as in Claim 20, wherein the information is communicated by the mobile unit using CDMA.

23. A system for managing mobile unit communication handoffs between a frequency division duplex (FDD) communication system and a time division duplex (TDD) communication system, the system comprising:

an FDD base station within the FDD communication system for communicating with the mobile unit in frequency division duplex mode, and for generating a pilot search signal corresponding to a transmission range of the FDD communication system;

a TDD base station within the TDD communication system for communicating with the mobile unit in time division duplex mode, and for generating a pilot search signal corresponding to a transmission range of the TDD communication system;

a mobile unit which is transmitting information via a current one of the FDD and TDD communication systems while moving towards the other, or targeted one of the FDD and TDD communication systems, the mobile unit comprising:

a receiving unit to receive the first and second pilot search signals, and to initiate a handoff from the current communication system to the targeted communication system when the pilot search signal from the targeted communication system has reached a predetermined threshold level; and

a dual-transceiver to synchronize concurrent communications between the mobile unit and the current and targeted communication systems, and to concurrently communicate the information with the current communication system and the targeted communication system upon synchronization, wherein the dual-transceiver comprises a burst mode capable of increasing a data rate between the mobile unit and the current and targeted communication systems during the handoff to concurrently support communication with both the current and targeted communications systems.

24. A method for maintaining a connection between a frequency division duplex (FDD) communication system and a time division duplex (TDD) communication system during handoff of a communication unit from one communication system to the other, the method comprising:

transmitting a first portion of a communication frame to one of the FDD and TDD communication systems;

transmitting a second portion of the communication frame to the other one of the FDD and TDD communication systems;

transmitting at least one of the first and second portions of the communication frame at an increased data rate; and

wherein communication occurs with both the FDD and TDD systems during the transmission of the communication frame, and wherein the communication occurs in a time equivalent to the time required to transmit the communication frame to either of the FDD and TDD systems when no handoff is occurring.

25. The method as in Claim 24, wherein:

transmitting the first portion of the communication frame comprises transmitting all of the communication frame to one of the FDD and TDD communication systems;

transmitting the second portion of the communication frame comprises transmitting all of the communication frame to the other one of the FDD and TDD communication systems; and

transmitting at least one of the first and second portions of the communication frame at an increased data rate comprises transmitting both the first and second portions of the communication frame at an increased data rate such that all of the communication frame is transmitted to both the FDD and TDD systems in a time equivalent to the time required to transmit the communication frame to either of the FDD and TDD systems when no handoff is occurring.

26. The method as in Claim 25, wherein transmitting both the first and second portions of the communication frame at an increased data rate comprises:

transmitting the first portion of the communication frame to the FDD communication system at a double rate; and

transmitting the second portion of the communication frame to the TDD communication system at a quadruple rate.

27. The method as in Claim 24, wherein a first portion of the communication frame is sent only to one, but not the other, of the FDD and

TDD systems, and a second portion of the communication frame is sent only to the other of the FDD and TDD systems.

28. The method as in Claim 27, wherein the communication frame is received and reconstructed by combining the first and second portions of the communication frames sent to the FDD and TDD systems.

29. The method as in Claim 27, wherein:

transmitting the first portion of the communication frame comprises transmitting a first half of the communication frame to one of the FDD and TDD communication systems;

transmitting the second portion of the communication frame comprises transmitting a second half of the communication frame to the other one of the FDD and TDD communication systems; and

transmitting at least one of the first and second portions of the communication frame at an increased data rate comprises transmitting the second half of the communication frame at an increased data rate such that the first half of the communication frame is transmitted to the FDD system at a non-increased data rate, and the second half of the communication frame is transmitted to the TDD system at a double data rate.

30. The method as in Claim 27, wherein a first number of subframes of the communication frame is sent only to one, but not the other, of the FDD and TDD systems, and a second number of subframes of the communication frame is sent only to the other of the FDD and TDD systems.

31. The method as in Claim 30, wherein at least one of the first number of subframes is transmitted in a different frequency than the other ones of the subframes.

32. The method as in Claim 31, wherein the frequency is changed using a predetermined pattern.

33. The method as in Claim 24, wherein the FDD and TDD communication systems operate in different frequency bands.

34. The method as in Claim 24, wherein the FDD and TDD communication systems are co-located and operate in different frequency bands.

35. The method as in Claim 24, wherein the FDD and TDD communication systems operate at least partly in a common frequency band.

36. The method as in Claim 24, wherein the handoff is requested by a mobile station in a cellular network.

37. A method for controlling information transmissions between a communications unit and frequency division duplex (FDD) and time division duplex (TDD) communication systems, wherein the communication unit is transmitting information via a first one of the FDD and TDD communication systems, the method comprising:

generating a cell identification signal corresponding to a transmission range of a second one of the FDD and TDD communication systems;

initiating substantially simultaneous communication between the communications unit and both the FDD and TDD communications systems when the communications unit acknowledges the cell identification signal and is thereby in the coverage area of both the FDD and TDD communications systems; and

maintaining the substantially simultaneous communication

between the communications unit and each of the FDD and TDD communications systems by simultaneously communicating at least a part of the information with each of the FDD and TDD communications systems.

38. The method of Claim 37, wherein simultaneously communicating at least a part of the information with each of the FDD and TDD communications systems comprises operating in a multirate mode such that an information transfer rate during the simultaneous communication of the information with each of the FDD and TDD communications systems is greater than the information transfer rate associated with only FDD information transmissions or only TDD information transmissions.

39. The method of Claim 37, wherein simultaneously communicating at least a part of the information with each of the FDD and TDD communications systems comprises simultaneously transmitting different portions of the information via the FDD and TDD communications systems respectively to provide for load sharing.

40. The method of Claim 37, wherein simultaneously communicating at least a part of the information with each of the FDD and TDD communications systems comprises simultaneously transmitting data via the TDD communications system while transmitting control signals via the FDD communications system.

41. The method of Claim 40, wherein the control signals are selected from the group of transmission rate control signals, power control signals, modulation control signals, and encoding control signals.

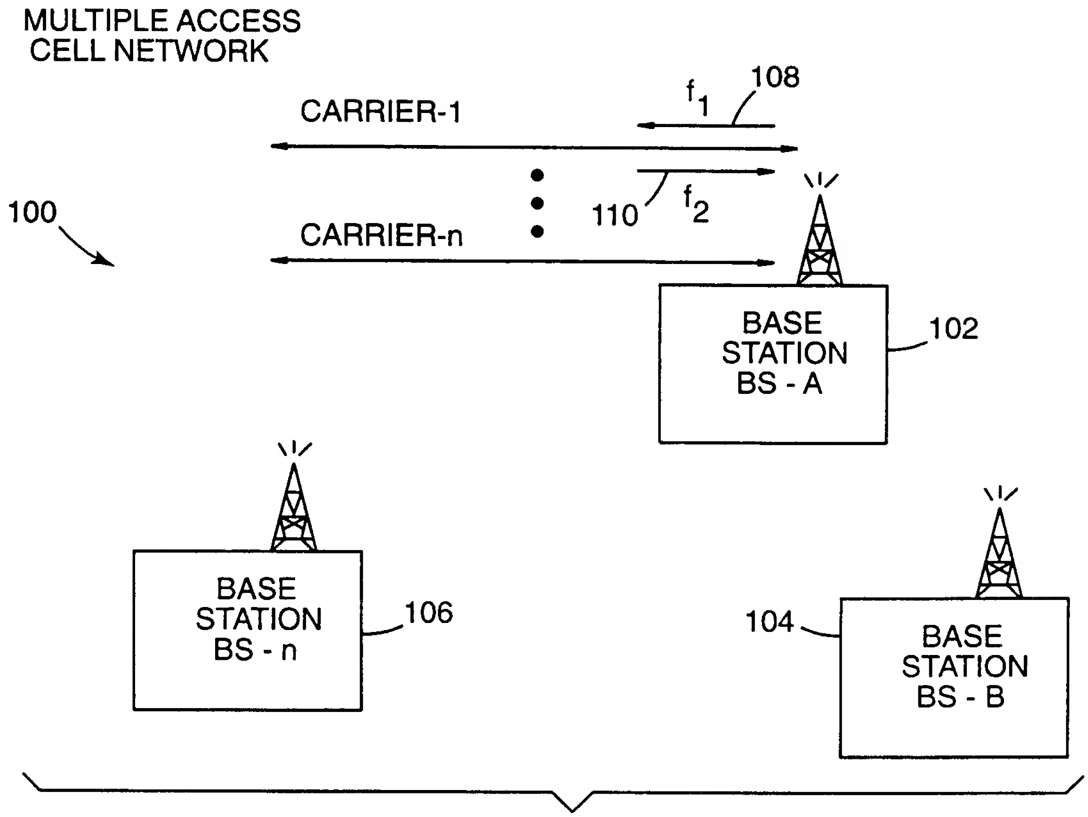

MULTIPLE ACCESS
CELL NETWORK
CARRIER-1
f_1
108
100
110
f_2
CARRIER-n
BASE
STATION
BS - A
102
BASE
STATION
BS - n
106
104
BASE
STATION
BS - B

Fig. 1

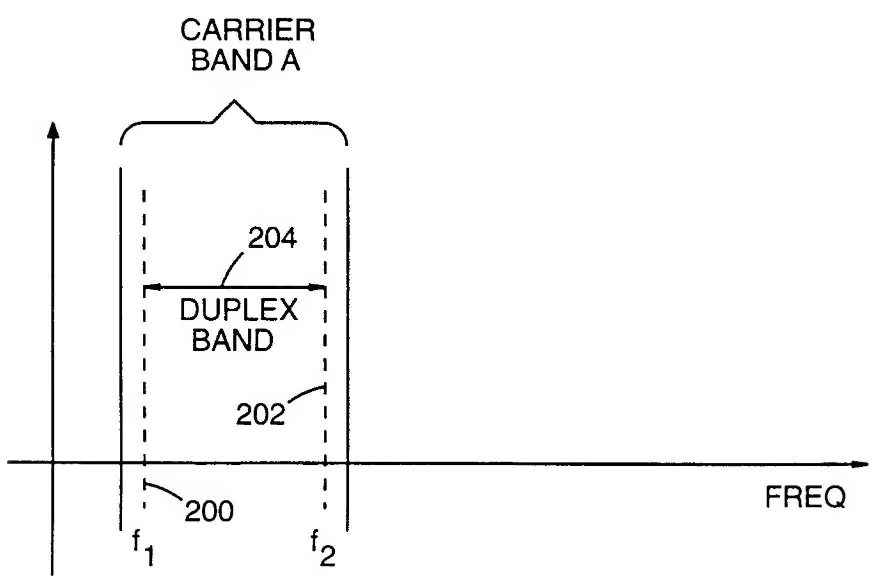

CARRIER
BAND A
204
DUPLEX
BAND
202
200
FREQ
f_1
f_2

Fig. 2

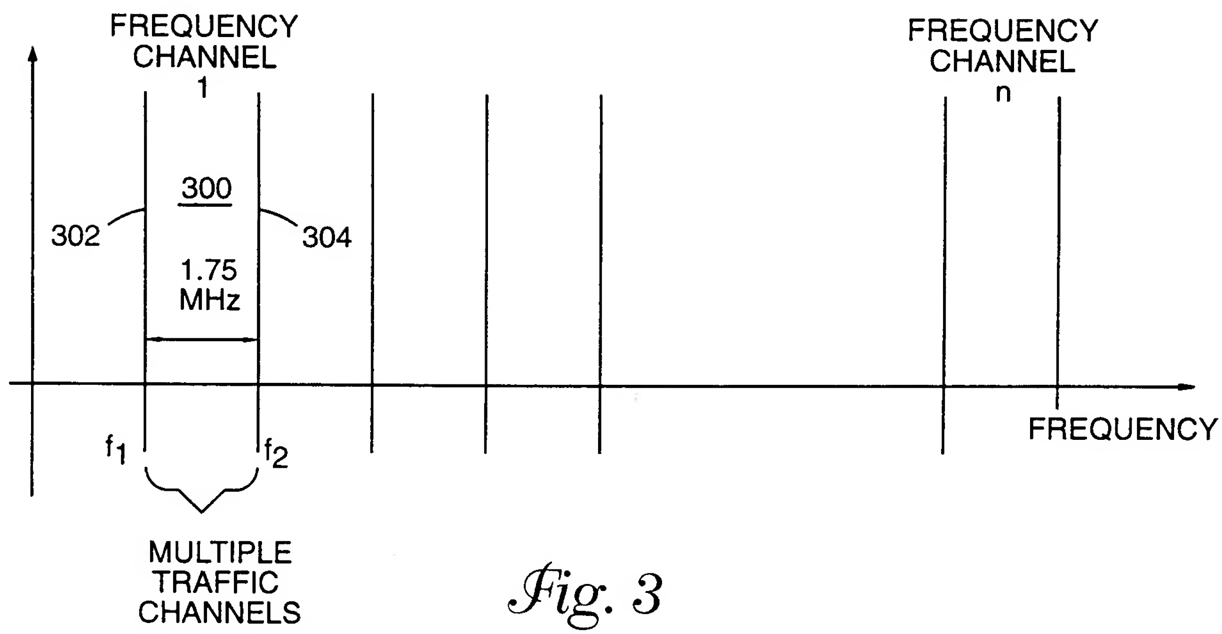

FREQUENCY
CHANNEL
1
FREQUENCY
CHANNEL
n
300
302
304
1.75
MHz
FREQUENCY
f_1
f_2
MULTIPLE
TRAFFIC
CHANNELS

Fig. 3

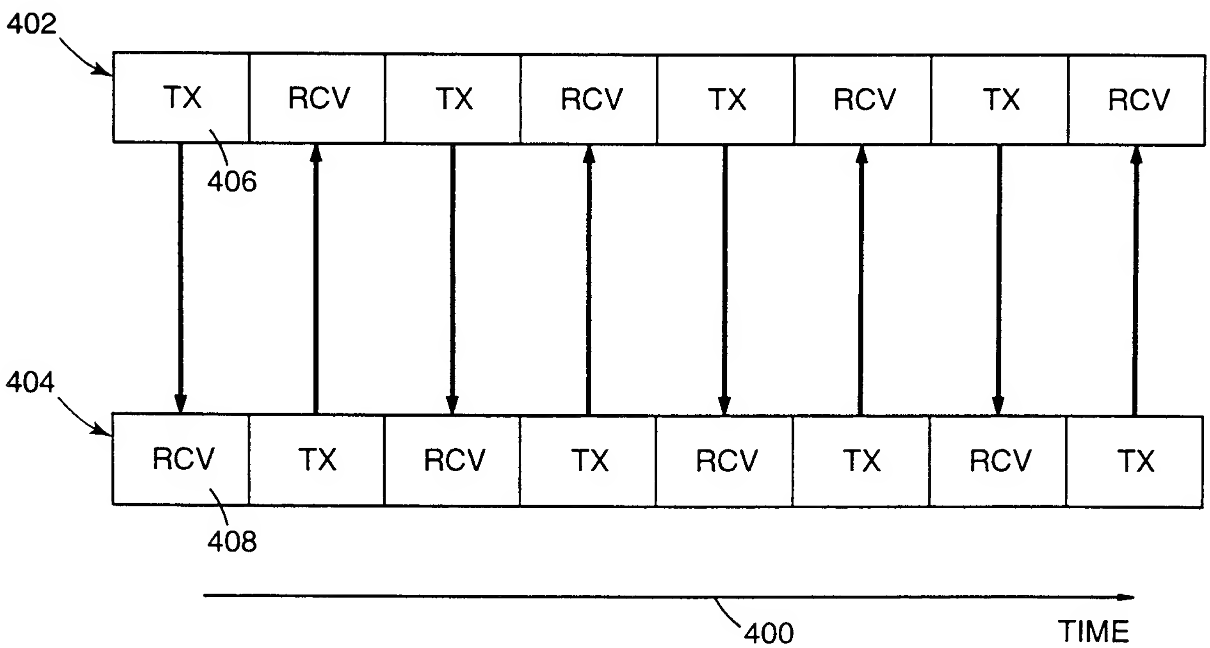

402
TX
RCV
TX
RCV
TX
RCV
TX
RCV
406
404
RCV
TX
RCV
TX
RCV
TX
RCV
TX
408
400
TIME

Fig. 4

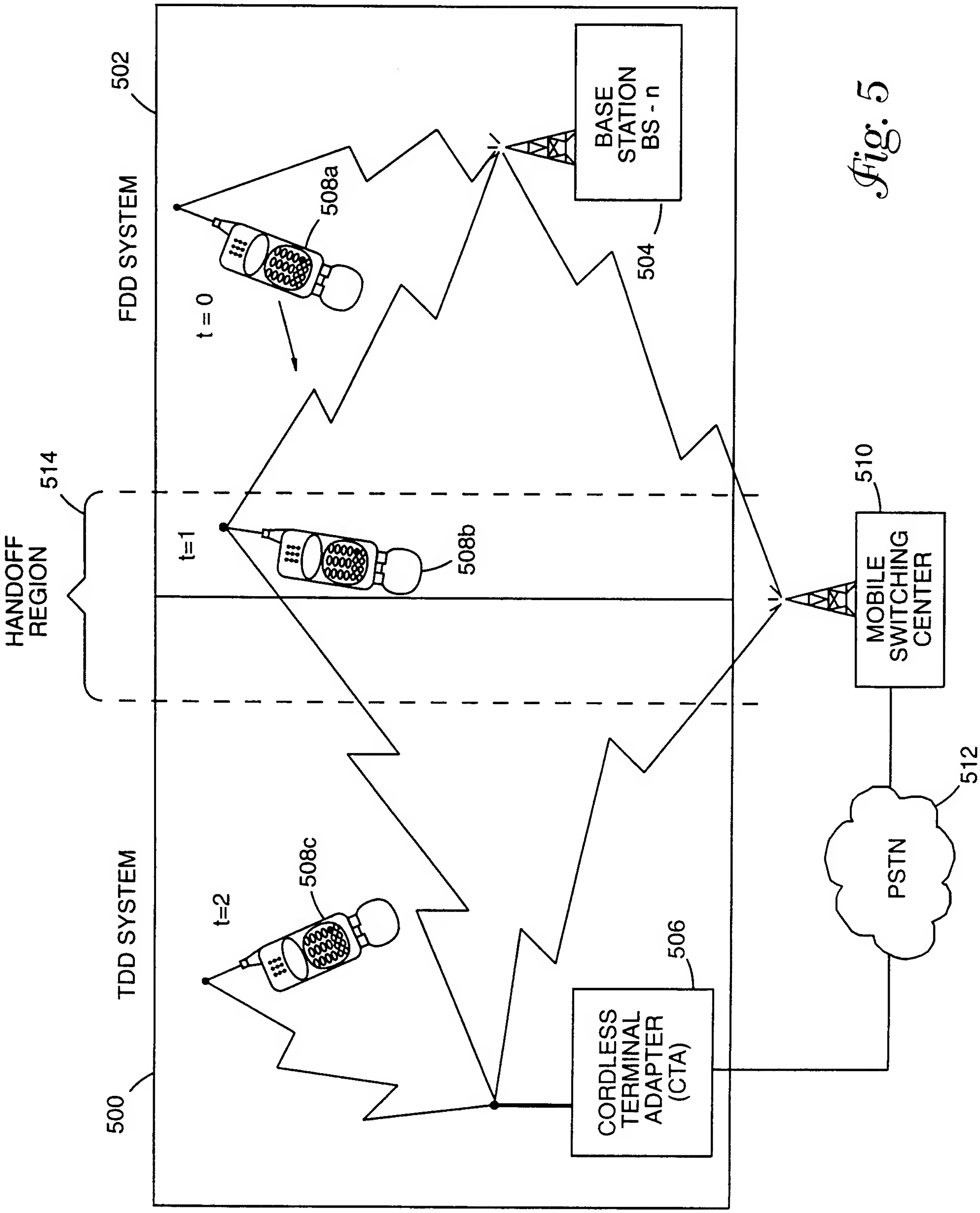

FDD SYSTEM
502
BASE STATION BS - n
504
508a
t = 0
HANDOFF REGION
514
t=1
508b
MOBILE SWITCHING CENTER
510
512
PSTN
TDD SYSTEM
t=2
508c
506
CORDLESS TERMINAL ADAPTER (CTA)
500

Fig. 5

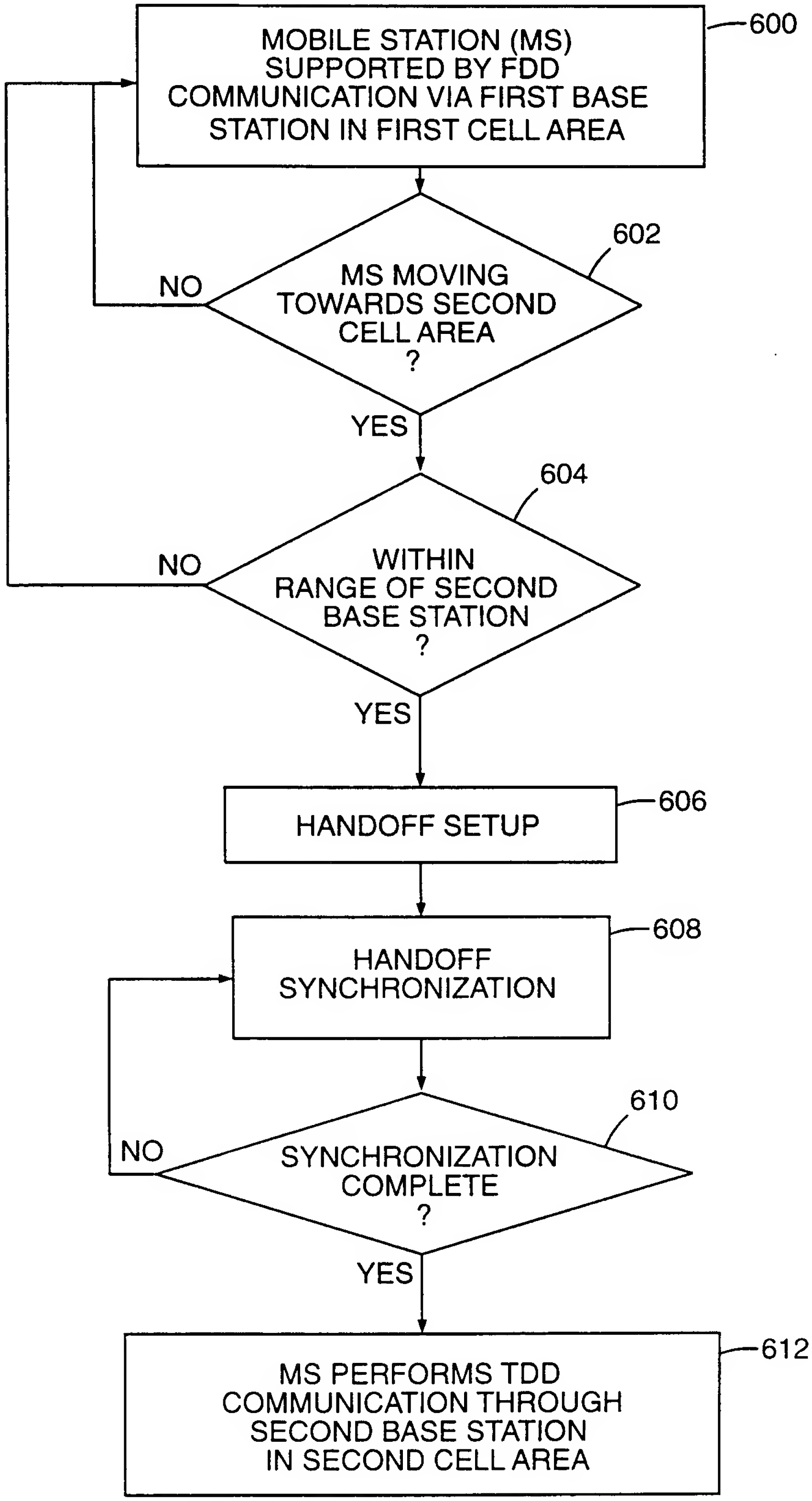
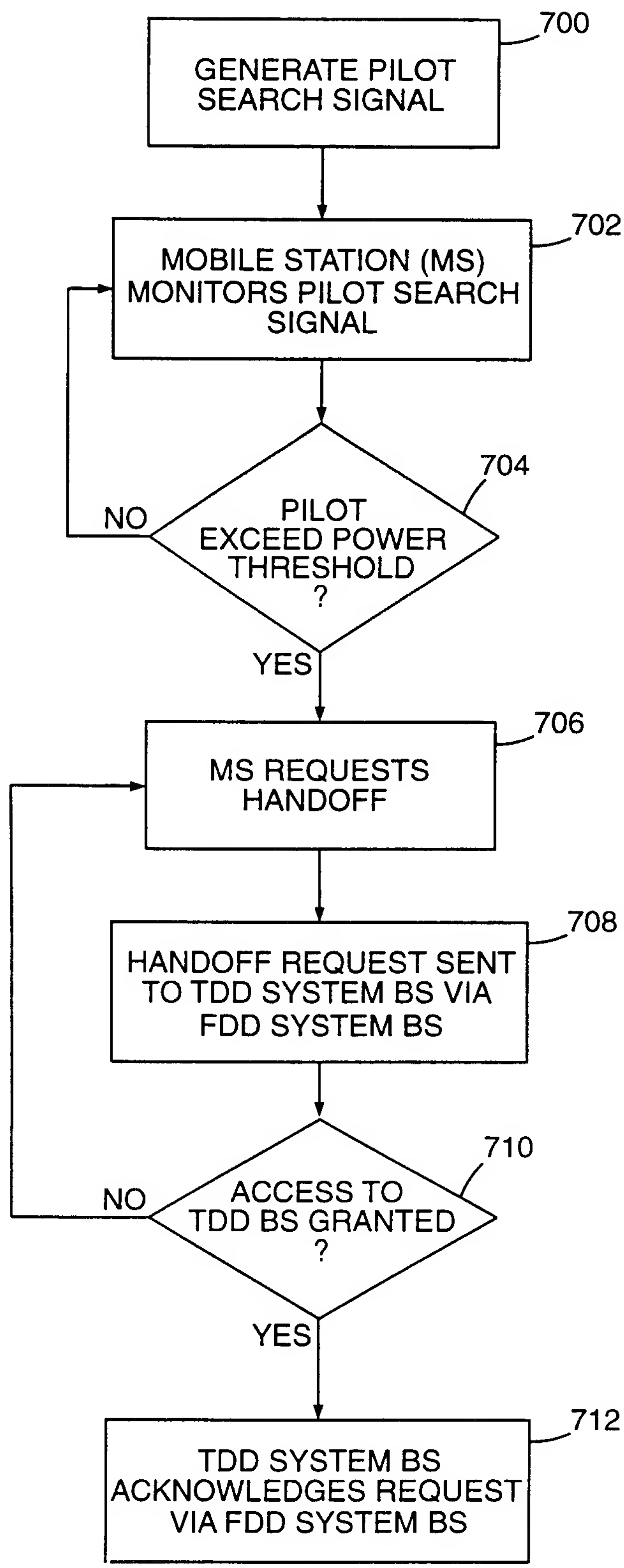
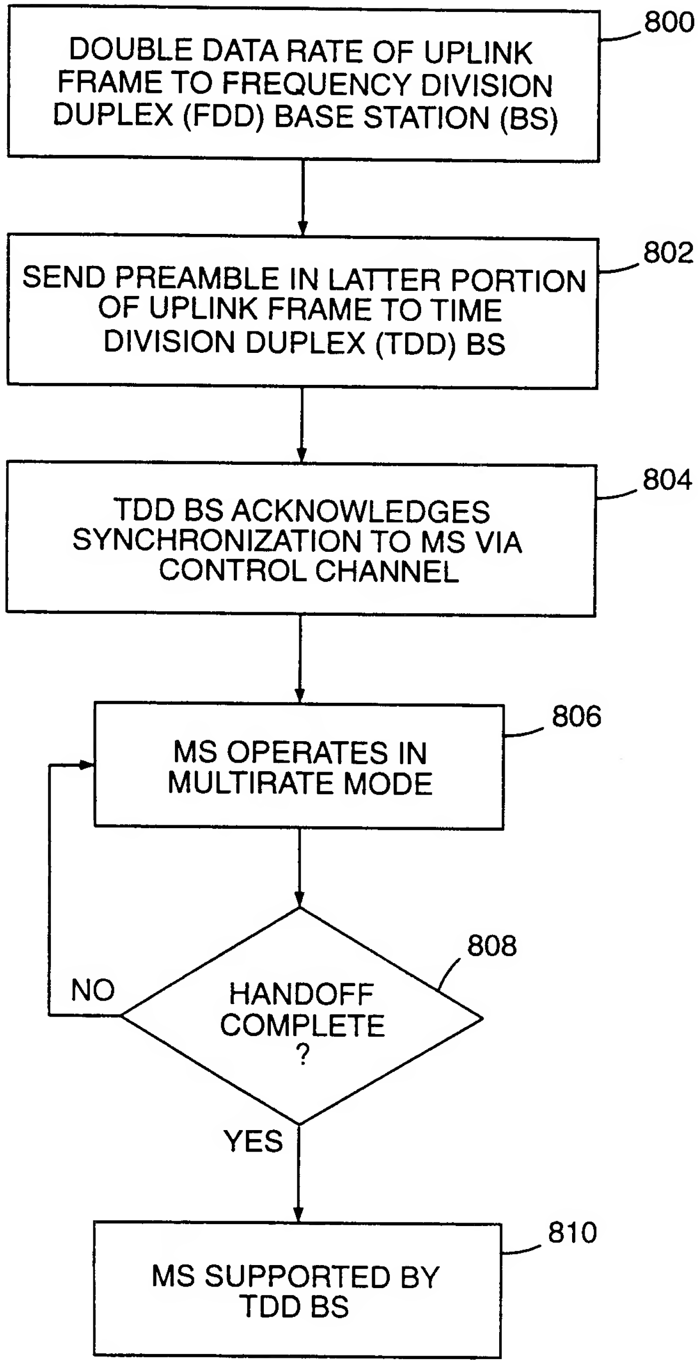

MOBILE STATION (MS) SUPPORTED BY FDD COMMUNICATION VIA FIRST BASE STATION IN FIRST CELL AREA
600
MS MOVING TOWARDS SECOND CELL AREA ?
602
NO
YES
WITHIN RANGE OF SECOND BASE STATION ?
604
NO
YES
HANDOFF SETUP
606
HANDOFF SYNCHRONIZATION
608
SYNCHRONIZATION COMPLETE ?
610
NO
YES
MS PERFORMS TDD COMMUNICATION THROUGH SECOND BASE STATION IN SECOND CELL AREA
612

Fig. 6



GENERATE PILOT SEARCH SIGNAL
700
MOBILE STATION (MS) MONITORS PILOT SEARCH SIGNAL
702
PILOT EXCEED POWER THRESHOLD ?
704
NO
YES
MS REQUESTS HANDOFF
706
HANDOFF REQUEST SENT TO TDD SYSTEM BS VIA FDD SYSTEM BS
708
ACCESS TO TDD BS GRANTED ?
710
NO
YES
TDD SYSTEM BS ACKNOWLEDGES REQUEST VIA FDD SYSTEM BS
712

Fig. 7



800
DOUBLE DATA RATE OF UPLINK FRAME TO FREQUENCY DIVISION DUPLEX (FDD) BASE STATION (BS)
802
SEND PREAMBLE IN LATTER PORTION OF UPLINK FRAME TO TIME DIVISION DUPLEX (TDD) BS
804
TDD BS ACKNOWLEDGES SYNCHRONIZATION TO MS VIA CONTROL CHANNEL
806
MS OPERATES IN MULTIRATE MODE
808
HANDOFF COMPLETE ?
NO
YES
810
MS SUPPORTED BY TDD BS

Fig. 8

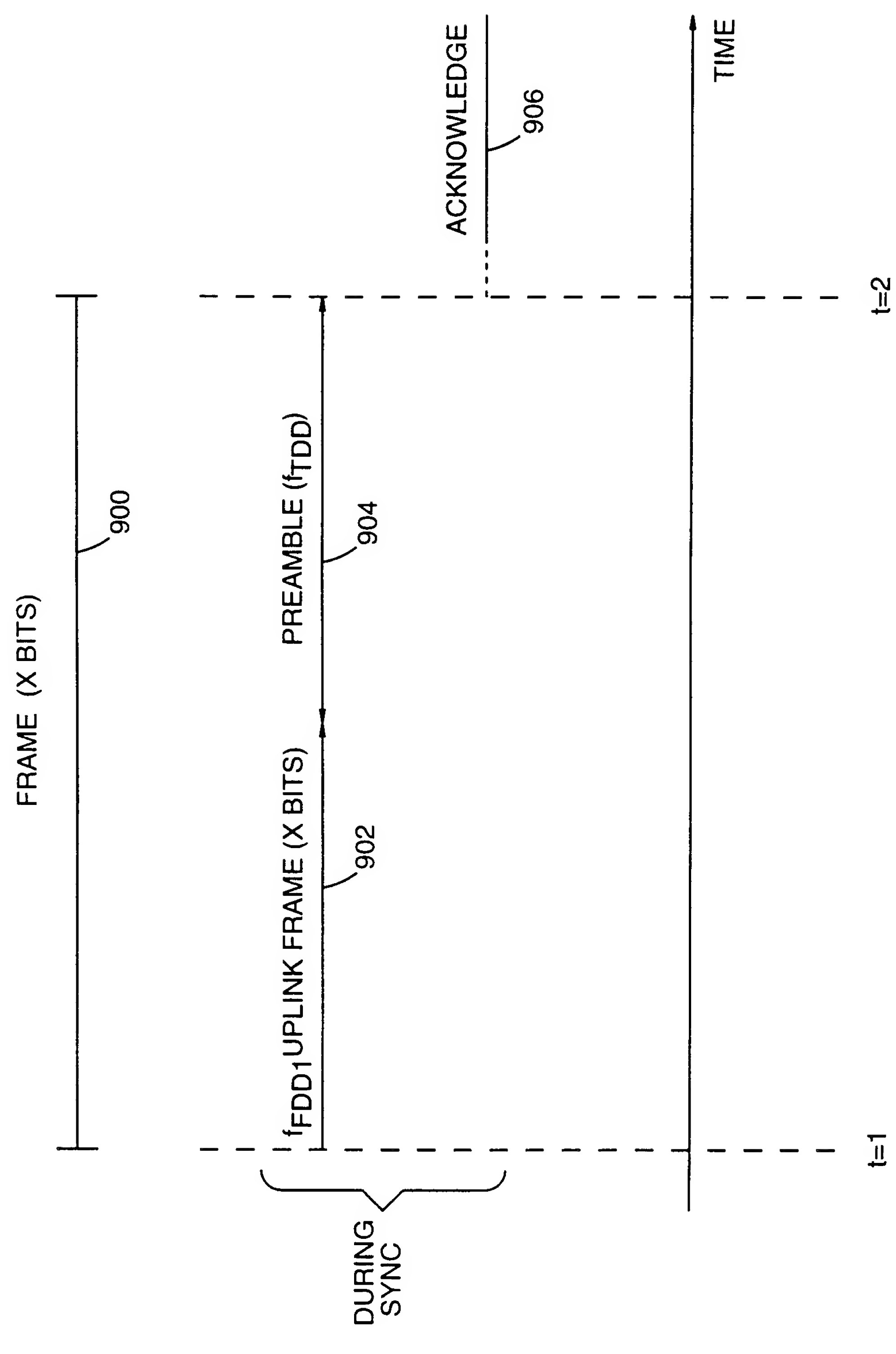

FRAME (X BITS)
900
f_{FDD1} UPLINK FRAME (X BITS)
902
PREAMBLE (f_{TDD})
904
ACKNOWLEDGE
906
TIME
t=1
t=2
DURING SYNC

Fig. 9A

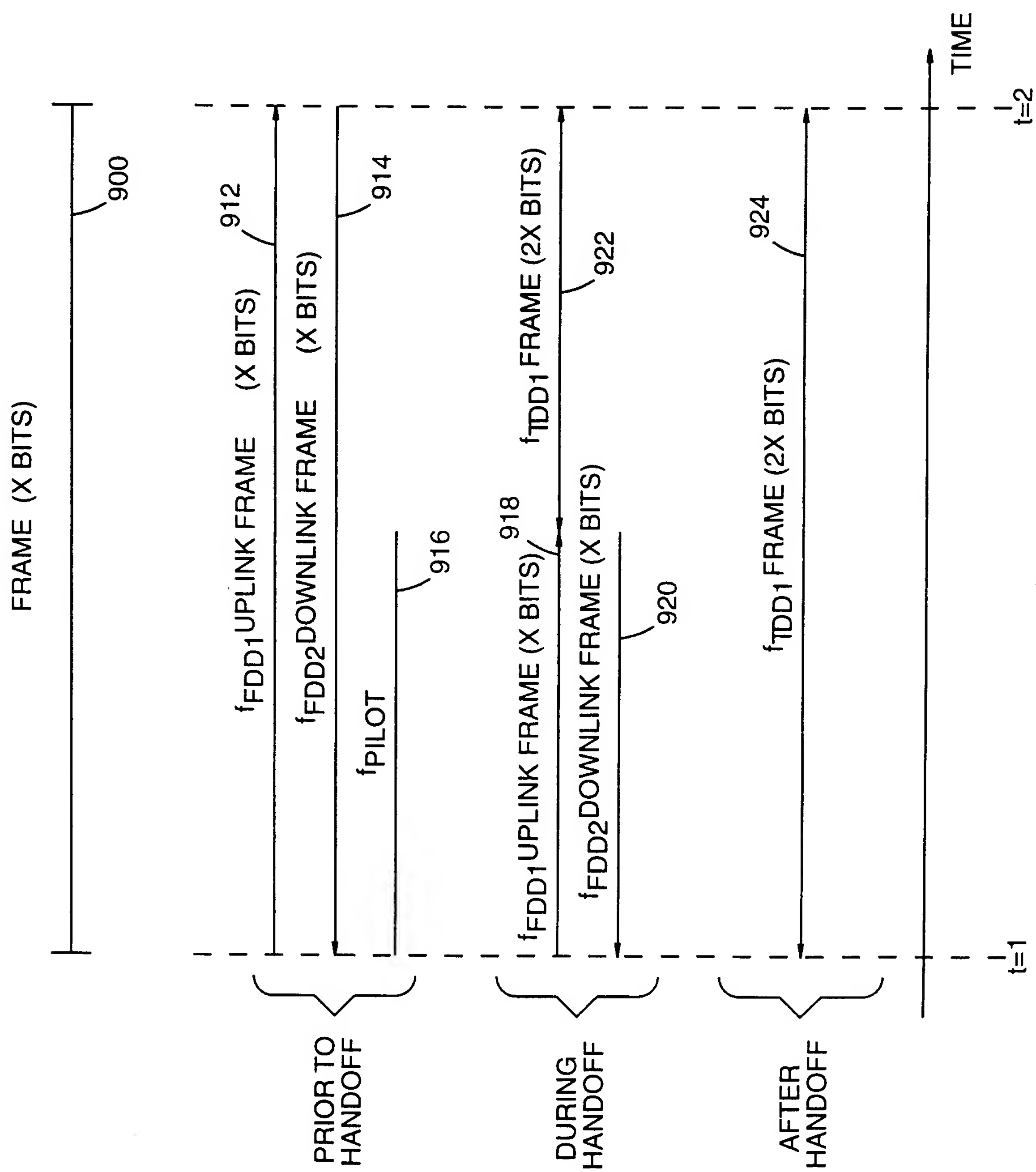

FRAME (X BITS)
900
f_{FDD1} UPLINK FRAME (X BITS)
912
f_{FDD2} DOWNLINK FRAME (X BITS)
914
f_{PILOT}
916
f_{FDD1} UPLINK FRAME (X BITS)
918
f_{TDD1} FRAME (2X BITS)
922
f_{FDD2} DOWNLINK FRAME (X BITS)
920
f_{TDD1} FRAME (2X BITS)
924
PRIOR TO HANDOFF
DURING HANDOFF
AFTER HANDOFF
TIME
t=1
t=2

Fig. 9B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/20074

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95 10922 A (NOKIA MOBILE PHONES LTD ;NOKIA TELECOMMUNICATIONS OY (FI); JAERVEL) 20 April 1995 (1995-04-20) the whole document	1-5
A	WO 96 23369 A (GIBBS JONATHAN ALASTAIR ;ROBINSON WILLIAM NEIL (GB); WHINNETT NICH) 1 August 1996 (1996-08-01) the whole document	1-41
A	WO 97 40592 A (ERICSSON TELEFON AB L M) 30 October 1997 (1997-10-30) page 11, line 18 -page 14, line 31 claims	1-41

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 October 2000	30/10/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Roberti, V

1

Inter onal Application No
PCT/US 00/20074

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	WHINNETT N W: "HANDOFF BETWEEN DISSIMILAR SYSTEMS: GENERAL APPROACHES AND AIR INTERFACE ISSUES FOR TDMA SYSTEMS" PROCEEDINGS OF THE VEHICULAR TECHNOLOGY CONFERENCE,US,NEW YORK, IEEE, vol. CONF. 45, 25 July 1995 (1995-07-25), pages 953-957, XP000551675 ISBN: 0-7803-2743-8 the whole document -----	1-41

1

INTERNATIONAL SEARCH REPORT

.formation on patent family members

Inter   onal Application No
PCT/US 00/20074

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		FI 982520 A	22-01-1999
		WO 9744984 A	27-11-1997

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(19) World Intellectual Property Organization
International Bureau

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(30) Priority Data:
09/409,981 30 September 1999 (30.09.1999) US

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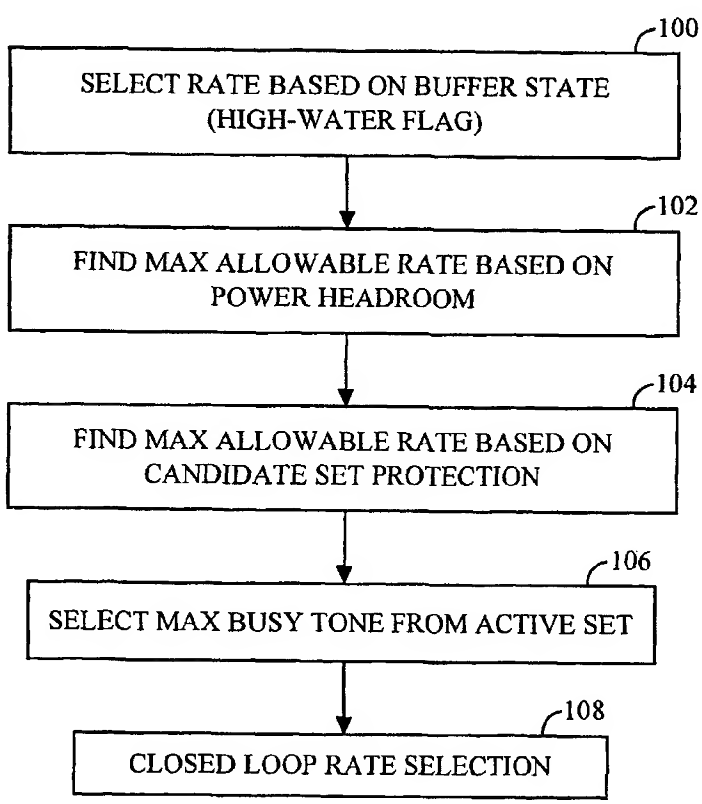
(54) **Title:** CLOSED LOOP RESOURCE ALLOCATION IN A HIGH SPEED WIRELESS COMMUNICATIONS NETWORK



(57) **Abstract:** Method and apparatus for performing transmission data rate allocation in a high speed wireless communications network. A macro control loop with the network of base stations on one side and all the subscriber stations on the other side. Subscriber station selects a rate based on the amount of data queued for transmission (100). Adjusts this rate based on the available power headroom of the subscriber station (102). This adjusted transmission rate is then adjusted again to account for protection of base stations in the candidate set of the subscriber station (104). This rate is then adjusted in accordance with busy tone signals indicative of the loading conditions of active set base stations of the subscriber station (108). The base stations react to these action by refreshing measurements of their instantaneous traffic load and providing feedback in the form of soft busy tones. The algorithm is named Closed Loop Resource Allocation.

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CLOSED LOOP RESOURCE ALLOCATION IN A HIGH SPEED WIRELESS COMMUNICATIONS NETWORK

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to wireless communications. More particularly, the present invention relates to a novel and improved method and apparatus for determining the transmission data rates in a high speed wireless communication system.

II. Description of the Related Art

A modern day communication system is required to support a variety of applications. One such communication system is a code division multiple access (CDMA) system which conforms to the "TIA/EIA/IS-95 Subscriber station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System", hereinafter referred to as the IS-95 standard. The CDMA system allows for voice and data communications between users over a terrestrial link. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Patent No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS", and U.S. Patent No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", both assigned to the assignee of the present invention and incorporated by reference herein.

In this specification, base station refers to the hardware with which the subscriber stations communicate. Cell refers to the hardware or the geographic coverage area, depending on the context in which the term is used. A sector is a partition of a cell. Because a sector of a CDMA system has the attributes of a cell, the teachings described in terms of cells are readily extended to sectors.

In the CDMA system, communications between users are conducted through one or more base stations. A first user on one subscriber station communicates to a second user on a second subscriber station by transmitting data on the reverse link to a base station. The base station receives the data and can route the data to another base station. The data is transmitted on the forward link of the same base station, or a second base station, to the second subscriber station. The forward link refers to transmission from the base

station to a subscriber station and the reverse link refers to transmission from the subscriber station to a base station. In IS-95 systems, the forward link and the reverse link are allocated separate frequencies.

The subscriber station communicates with at least one base station during a communication. CDMA subscriber stations are capable of communicating with multiple base stations simultaneously during soft handoff. Soft handoff is the process of establishing a link with a new base station before breaking the link with the previous base station. Soft handoff minimizes the probability of dropped calls. The method and system for providing a communication with a subscriber station through more than one base station during the soft handoff process are disclosed in U.S. Patent No. 5,267,261, entitled "MOBILE ASSISTED SOFT HANDOFF IN A CDMA CELLULAR TELEPHONE SYSTEM," assigned to the assignee of the present invention and incorporated by reference herein. Softer handoff is the process whereby the communication occurs over multiple sectors which are serviced by the same base station. The process of softer handoff is described in detail in copending U.S. Patent Application Serial No. 08/763,498, entitled "METHOD AND APPARATUS FOR PERFORMING HANDOFF BETWEEN SECTORS OF A COMMON BASE STATION", filed December 11, 1996, assigned to the assignee of the present invention and incorporated by reference herein

Given the growing demand for wireless data applications, the need for very efficient wireless data communication systems has become increasingly signicant. The IS-95 standard is capable of transmitting traffic data and voice data over the forward and reverse links. A method for transmitting traffic data in code channel frames of fixed size is described in detail in U.S. Patent No. 5,504,773, entitled "METHOD AND APPARATUS FOR THE FORMATTING OF DATA FOR TRANSMISSION", assigned to the assignee of the present invention and incorporated by reference herein. In accordance with the IS-95 standard, the traffic data or voice data is partitioned into code channel frames which are 20 msec wide with data rates as high as 14.4 Kbps.

A system completely dedicated to high speed wireless communications is disclosed in copending U.S. Patent Application Serial No. 08/963,386 (the '386 application), filed November 3, 1997, entitled, "METHOD AND APPARATUS FOR HIGHER RATE PACKET DATA TRANSMISSION", which is assigned to the assignee of the present invention and incorporated by reference herein. In the '386 application, the base station transmits to subscriber stations by sending frames that include a pilot burst time multiplexed in to the frame and transmitted at a rate based on channel information transmitted from the subscriber station to the base station.

A significant difference between voice services and data services is the fact that the former imposes stringent and fixed delay requirements. Typically, the overall one-way delay of speech frames must be less than 100 msec. In contrast, the data delay can become a variable parameter used to optimize the efficiency of the data communication system. Specifically, more efficient error correcting coding techniques which require significantly larger delays than those that can be tolerated by voice services can be utilized. An exemplary efficient coding scheme for data is disclosed in U.S. Patent Application Serial No. 08/743,688, entitled "SOFT DECISION OUTPUT DECODER FOR DECODING CONVOLUTIONALLY ENCODED CODEWORDS", filed November 6, 1996, assigned to the assignee of the present invention and incorporated by reference herein.

Another significant difference between voice services and data services is that the former requires a fixed and common quality of service (QOS) for all users. Typically, for digital systems providing voice services, this translates into a fixed and equal transmission rate for all users and a maximum tolerable value for the error rates of the speech frames. In contrast, for data services, the QOS can be different from user to user, can be negotiated, and should be subject to some fairness constraints. The QOS that a data communication system provides to a subscriber is typically described by the delay, average throughput, blockage probability, connection loss probability experienced during service time.

A wireless data communication system can typically provide a range of transmission data rates both in the forward and reverse links. These transmission data rates are allocated to the various active traffic sources according to a strategy, identified as medium access control, that must account for the fact that the sources typically offer different incoming information data rates, depending essentially on the selected data application. Also, channel conditions and overall system load should be considered when allocating transmission data rate to a specific subscriber.

Medium access control amounts to allocating the resource to the active subscriber stations in the network in a way that optimizes the trade-off between overall system throughput, QOS, and algorithm complexity. While in the forward link one can exploit the "one-to-many" nature of the transmission to perform optimal centralized resource allocation at the base station, in the "many-to-one" reverse link the problem of optimization of the medium access control strategy is complex, and can be solved with a centralized approach at the base station, or with a distributed approach at the subscriber stations. Although many of the techniques described herein may be extended to the

medium access control of the forward link signals, the focus of the present invention is set on medium access control for the reverse link.

The information that should be used to perform resource allocation in the reverse link resides both at the network of base stations and at the subscriber stations. Specifically, at the network side resides the information pertaining to the instantaneous traffic load and spare capacity of each base station. The load can be quantified for example by the rise of the overall received energy over the floor set by the noise power spectral density. The spare capacity is the difference between the maximum allowable load that prevents network instability and the instantaneous load. At the subscriber station resides information about terminal class (for example maximum transmission power, transmission buffer size, supported data rate set), channel conditions (for example signal-to-noise plus interference ratio for all received pilots, transmit power headroom), and traffic source state (for example buffer state, buffer overflow, average throughput in the past, delay statistics). In principle, information can be exchanged between the network and the subscribers, but this involves signaling over the air interface which implies a waste of resources and a delay in the decision making process.

A first problem is therefore to design a medium access control strategy for the reverse link that exploits in an optimal way the available information minimizing signaling messages. Also, it is desirable for the medium access control strategy to be robust in terms of changes in the subscriber station class and in the network topology. Another fundamental problem is resource allocation for a subscriber station in soft handoff. In this case the traffic load and spare capacity of all base stations involved in the soft-handoff (identified as base stations in the active set) must be considered, again possibly minimizing signaling in the network. Yet another fundamental problem is protection of base stations that are not in soft handoff with a particular subscriber station, but that nevertheless are connected to that subscriber station through an electromagnetic link with path loss comparable to those measured in the active set. These base stations are referred to herein as the candidate set.

The present invention, described in the following, is an efficient and novel method and apparatus designed to address and solve all the above mentioned fundamental problems for a reverse link medium access control strategy.

SUMMARY OF THE INVENTION

The present invention is a novel and improved method and apparatus for performing transmission data rate allocation in the reverse link of a high speed wireless communications network. The present invention forms a macro control loop with the network of base stations on one side and all the subscriber stations on the other side. Each subscriber station selects a data rate based on the amount of data queued for transmission. Adjusts this rate based on the available power headroom. This adjusted transmission rate is then adjusted again to account for protection of base stations in the candidate set of the subscriber station. This rate is then adjusted in accordance with signals indicative of the loading conditions of active set base stations of the subscriber station. The base stations react to the subscriber stations action by measuring their instantaneous traffic load and providing feedback in the form of soft busy tones. The method is referred to herein as Closed Loop Resource Allocation.

It is an objective of the present invention to optimize reverse link medium access control by placing the data rate allocation under the control of the subscriber station which has a greater amount of information by which to determine the transmission rate than do the elements on the network side. The subscriber has information regarding the amount of information it has queued to transmit, and the amount of available transmit power headroom, the signal-to-noise plus interference ratios in both the active set and the candidate set links, all of which are essential factors in selecting a reverse link transmission rate. The base stations do not have this information absent a significant amount of signaling, which is undesirable.

It is another objective of the present invention to prevent a subscriber station from creating unacceptable interference to candidate base stations by its reverse link transmission, thus enforcing candidate set protection.

It is another objective of the present invention to allow data rate allocation on a per-packet basis, to provide the flexibility that is necessary to provide efficient service to subscriber stations offering traffic with high burstiness.

It is another objective of the present invention to provide fairness in resource allocation among the subscriber stations by taking into account the average throughput in the recent past and the possible buffer overflow condition.

It is another objective of this invention to provide efficient reverse link medium access control without requiring any signaling in the backhaul, between base station transceivers and base station controllers, even when the

subscriber station is in soft handoff. This is highly desirable because it makes resource allocation independent from the network architecture and the associated transmission and processing delays.

It is another objective of the present invention to minimize the necessary signaling on the air interface.

It is another objective of the present invention to avoid resource waste that occurs when the rate used by the subscriber station is smaller than the allocated rate. In fact, in closed loop resource allocation the allocated rate and the used rate are always coincident.

It is yet another objective of the present invention to provide soft multi-bit busy tones that indicate not only whether a base station is in an overload condition or not, but also provides some indication of the extent of its loading.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIGS. 1A-1F are flowcharts illustrating the method of rate allocation of the present invention;

FIG. 2 is a diagram illustrating the basic elements of the wireless communication system network of the present invention;

FIGS. 3A-3B are block diagrams illustrating the base station of the exemplary embodiment of the present invention;

FIGS. 4A-4B are frame diagrams illustrating the exemplary forward link frame format of the present invention; and

FIG. 5 is a block diagram of the exemplary subscriber station of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

I. Method Overview

FIG. 1A is a flowchart describing the preferred method of performing closed loop resource allocation according to the present invention. It will be understood by one skilled in the art that the steps illustrated in the FIG. 1A represent no preferred ordering sequence and that the order of the steps may

be changed without departing from the scope of the present invention. Moreover, steps of the present invention may be eliminated altogether without departing from the scope of the present invention. In the exemplary embodiment, the present invention is employed to determine the data rate of reverse link transmissions from a subscriber station. In block **100**, the subscriber station selects an initial desired rate (R_{step1}) based on the buffer state. In the exemplary embodiment, the data rate is determined on a per packet basis.

FIG. 1B is a flowchart describing the rate selection based on the buffer state in greater detail. In block 110, the subscriber station determines the number of bytes in its transmit buffer (Q_{length}).

In block 112, the subscriber station determines the parameters R_{min} and R_{max}. R_{min} and R_{max} are the minimum rate and the maximum rate at which the subscriber station is capable of transmitting. In the exemplary embodiment, R_{max} for a particular subscriber station can optionally be set by the serving base station by means of over the air signaling. An exemplary set of rates (R) in Kbps and corresponding packet sizes ($P_{size}(R)$) in information bytes for those rates is illustrated in Table 1 below.

Rate (R) (kb/s)	4.8	9.6	19.2	38.4	76.8	153.6	307.2
Packet size (byte) ($P_{size}(R)$)	32	64	128	256	512	1024	2048

In control block 114, the subscriber station determines whether the number of bytes of information in the transmit buffer is greater than the packet size for the maximum transmission rate. In the case of the exemplary numerology, the maximum rate is 307.2 Kbps and the corresponding maximum packet size is 2048 bytes. If the number of bytes of information in the transmit buffer is greater than the packet size for the maximum transmission rate, then in block 116 variable R_{buffer} is set equal to R_{max}. If the number of bytes of information in the transmit buffer is not greater than the packet size for the maximum transmission rate, then in block 118 variable R_{buffer} is set to the lowest available rate at which the entire contents of the transmit buffer (Q_{length}) can be transmitted in a single packet.

In block 119, the subscriber station determines the rate of its last transmission ($R_{previous}$). In the preferred embodiment, this value is stored in

RAM and overwritten after each transmission. In block 120, a temporary rate variable R_{step1} is set to the minimum of either the rate indicated by R_{buffer} or twice the rate $R_{previous}$.

In the exemplary embodiment, the buffer of the subscriber station is separated into two portions. A first portion includes new data for transmission and the second portion includes RLP (Radio Link Protocol) data, which are packets that were previously transmitted but could be retransmitted. In the preferred embodiment, a flag F_{buffer} is set when the new data buffer of the subscriber station is nearly full. In response to the setting of the nearly full buffer flag, the subscriber station adjusts is rate selection algorithm. In a first exemplary embodiment, the subscriber station adjusts the rate selection algorithm so as to bias its transmission rate to one of increasing the transmission rate, as will be described in greater detail further in. In an alternative embodiment, the subscriber station transmits at a predetermined higher rate. It will be understood that one skilled in art can modify the responses to the setting of a full buffer flag so as to increase the transmission rate in a variety of ways that are all within the scope of the present invention. For fairness, the F_{buffer} flag should not be set for more than N_{buffer} times (e.g. 25) out of the last 100 packets.

Returning to FIG. 1, the operation moves to block 102 wherein the subscriber station determines the maximum rate based on the power headroom (R_{step2}). FIG. 1C illustrates the operation performed in step 102 is greater detail. In block 122, the subscriber station determines the maximum transmit power (P_{max}) at which the subscriber station is capable of operating. In the exemplary embodiment, the maximum transmit power depends on the power amplifier in the subscriber station be it mobile or fixed, and on the amount of battery energy in the subscriber station if the subscriber station is mobile.

In block 124, the subscriber station computes a maximum allowed transmit power which is the maximum transmit power P_{max} (dB) determined in step 122 less a power margin P_{margin} (dB), that allows to track future power level fluctuations. Then, the subscriber station sets a variable R_{power} equal to the max rate, R, which can be reliably transmitted with a power, P(R) (dB), less than the maximum allowed transmit power (P_{max} (dB) - P_{margin} (dB)). In block 126, the subscriber station sets a new variable R_{step2} equal to the minimum of R_{step1} determined in step 100 and R_{power} determined in step 124.

Returning to FIG. 1A, the process then moves to block 104 where the subscriber station determines the maximum transmission rate in accordance with a candidate set protection criterion. The purpose of the rate adjustment in step 104 is to protect members of the candidate set of the subscriber station

from having their reverse links overloaded by subscriber stations not in communication with them but which are sufficiently visible (in terms of path loss) to cause interference problems.

In the exemplary embodiment, the subscriber station is not informed of loading problems of base stations in the candidate set, because it does not receive the pertinent busy tone. Thus, the candidate set protection algorithm is provided for preventing uncontrolled overload of the candidate set base stations. In the exemplary embodiment, the amount of reduction in the maximum allowable rate of transmission is based upon the strength of the pilot signals from the candidate base stations. In particular, the strength of the pilot signals from the candidate base stations relative to the strength of the pilot signals from the active set base stations.

FIG. 1D illustrates the exemplary method for determining the maximum transmission rate in accordance with protection of the candidate set. In block 128, the subscriber station measures the Ec/Io of the pilot signals from each of the base stations in its candidate set which includes all the multipath components of the pilot signals from those base stations. In block 130, the subscriber station measures the Ec/Io of the pilot signals from each of the base stations in its active set which includes all the multipath components of the pilot signals from those base stations.

In block 132, the subscriber station computes a metric (Δ_{ac}) that is a function of the difference in strength of the signals received by base stations in the active set and signals received by base stations in the candidate set. In the exemplary embodiment, the metric (Δ_{ac}) is set to the difference between the sum of the Ec/Io of the all member of the active set in decibels, and the sum of the Ec/Io of the all the members in the candidate set in decibels, as illustrated in equation (1) below:

$$\Delta_{ac} = \left[\sum_i E_c^a(i)/I_o\right](\mathrm{dB}) - \left[\sum_j E_c^c(j)/I_o\right](\mathrm{dB}), \qquad (1)$$

where $E_c^a(i)/I_o$ is the strength of the ith pilot of the active set including all related multipath components, and $E_c^c(j)/I_o$ is the strength of the jth pilot in the candidate set including all related multipath components.

In a first alternative embodiment, the metric (Δ_{ac}) is set to the difference between the weakest member of the active set and the strongest member of the candidate set as illustrated in equation (2) below:

$$\Delta_{ac} = \min_i\left\{E_c^a(i)/I_o(\mathrm{dB})\right\} - \max_j\left\{E_c^c(j)/I_o(\mathrm{dB})\right\}, \tag{2}$$

where $E_c^a(i)/I_o$ is the strength of the ith pilot of the active set including all related multipath components, and $E_c^c(j)/I_o$ is the strength of the jth pilot in the candidate set including all related multipath components.

In a second alternative embodiment, the metric (Δ_{ac}) is set to the difference between the weakest member of the active set and the sum of the members of the candidate set as illustrated in equation (3) below:

$$\Delta_{ac} = \min_i\left\{E_c^a(i)/I_o(\mathrm{dB})\right\} - \left[\sum_j E_c^c(j)/I_o\right](\mathrm{dB}), \tag{3}$$

where $E_c^a(i)/I_o$ is the strength of the ith pilot of the active set including all related multipath components, and $E_c^c(j)/I_o$ is the strength of the jth pilot in the candidate set including all related multipath components.

In a third alternative embodiment, the metric (Δ_{ac}) is set to the difference between the strongest member of the active set and the strongest member of the candidate set as illustrated in equation (4) below:

$$\Delta_{ac} = \max_i\left\{E_c^a(i)/I_o(\mathrm{dB})\right\} - \max_j\left\{E_c^c(j)/I_o(\mathrm{dB})\right\}, \tag{4}$$

where $E_c^a(i)/I_o$ is the strength of the ith pilot of the active set including all related multipath components, and $E_c^c(j)/I_o$ is the strength of the jth pilot in the candidate set including all related multipath components.

A fourth alternative embodiment computes the metric based on the selection of the pilot in the active set that is driving the power control algorithm.

Other methods of determining the metric will be evident to one skilled in the art and are within the scope of the present invention.

In block 134, a variable R_{can} is set to the maximum rate (R) such that the difference between the power necessary to transmit a packet from the subscriber station at rate R, P(R) (dB), less a protection factor, exceeds the computed metric value (Δ_{ac}). In the exemplary embodiment, the protection factor is determined as the power in decibels required to transmit at a rate that is equal to N_{prot} times R_{min}, where N_{prot} is an integer scaling factor and R_{min} is the minimum rate at which the subscriber station is capable of transmitting.

In block 136, a variable R_{step3} , which is the adjusted rate after performing the candidate set protection operation, is determined by selecting the minimum rate of either R_{step2} or R_{can}.

Returning to FIG. 1A, in block 106, the subscriber station selects the maximum busy tone from the ones received from all base stations in the active set. In a simple case, where the busy tone is a single bit indicative of either the reverse link capacity loading condition or the existence of additional reverse link capacity, the selection of the maximum busy tone is simply a matter of OR-ing all of the received busy tones. If any of the busy tones indicates a capacity loading condition, the subscriber station stochastically reduces the rate of its transmissions, as described later. If all the busy tones indicate additional reverse link capacity, then the subscriber station stochastically increases its transmission rate, as described later.

In the preferred embodiment, the busy tone is a soft multi-bit busy tone, namely with two bits (b1,b2) which corresponds to the meanings in Table 2 below.

Table 2

(b1,b2)	Meaning
(0,0)	Base Station Scarcely Loaded
(0,1)	Base Station Stable
(1,0)	Base Station Highly Loaded
(1,1)	Base Station Overload

FIG. 1E illustrates an exemplary method for determining the values of the two bit busy tone. In block 138, the base station estimates its reverse link loading. There are a plurality of methods for estimating reverse link loading all of which are applicable to the present invention. The exemplary embodiment for estimating reverse link loading is described in detail in U.S. Patent Application Serial No. 09/204,616, entitled "Method and Apparatus for Loading Estimation", which is assigned to the assignee of the present invention and incorporated by reference herein.

In block 140, the base station compares the estimated reverse link loading to a first threshold value (TH1). If the estimated reverse link loading is less than the threshold value TH1, then the base station reverse link is determined to be scarcely loaded and in block 142, the busy tone bits are set to (0,0). If the estimated reverse link loading is greater than or equal to TH1 then the operation moves to block 144.

In block 144, the base station compares the estimated reverse link loading to a second threshold value (TH2). If the estimated reverse link loading is less than the threshold value TH2, then the base station reverse link is determined to be stable and in block 146, the busy tone bits are set to (0,1). If the estimated reverse link loading is greater than or equal to TH2 then the operation moves to block 148.

In block 148, the base station compares the estimated reverse link loading to a third threshold value (TH3). If the estimated reverse link loading is less than the threshold value TH3, then the base station reverse link is determined to be heavily loaded and in block 150, the busy tone bits are set to (1,0). If the estimated reverse link loading is greater than or equal to TH3 then the operation moves to block 152. In block 152, the base station is determined to be over loaded and the busy tones are set to (1,1).

All of the threshold comparisons can be implemented through hysteresis cycles to prevent too frequent crossing.

In block 106, the subscriber station receives the busy tones from all of the base stations in its active set and selects the highest busy tone.

In block 108, the rate of transmission for the current packet is selected in accordance with the maximum busy tone (b1,b2) selected in step 106. FIG. 1F illustrates the method of rate selection based on the selected maximum busy tone.

In control block 154, the subscriber station determines whether the maximum busy tone (b_1,b_2) has the value (0,0), which would indicate that all the base stations in its active set are scarcely loaded. In this case, deterministic rate increase is possible; the operation moves to control block 156, and the rate of transmission of the packet is set to R_{step3}. If the maximum busy tone does not have the value (0,0), the operation moves to control block 158.

In control block 158, the subscriber station determines whether the maximum busy tone (b_1,b_2) has the value (0,1), which would indicate that at least one base station in its active set is stable (but not scarcely loaded). If the maximum busy tone has the value (0,1), the operation moves to control block 160, where stochastic rate increase is possible. In control block 160, the subscriber station determines whether the computed rate R_{step3} is less than or equal to $R_{previous}$. If R_{step3} is less than or equal to $R_{previous}$, then in block 162 the current packet is transmitted at rate R_{step3}. If R_{step3} is greater than $R_{previous}$, then in block 164 the current packet is transmitted at a stochastically determined rate such that the packet is transmitted at rate R_{step3} with probability p or is transmitted at rate $R_{previous}$ with probability 1-p. If the maximum busy tone does not have the value (0,1), the operation moves to control block 166.

In the exemplary embodiment, the probability (p) of increasing the transmission rate of the subscriber station is determined in accordance with past activity of the subscriber station and on the buffer nearly full flag (F_{Buffer}). In particular, in the exemplary embodiment, the probability is determined in accordance with the average rate used in a predetermined number of previous packets, $R_{average}$. In the exemplary embodiment, the probability is determined in accordance with the equation:

$$p = \min\left\{1, \frac{1 + F_{Buffer}/2}{N_{rates}} \log_2 \frac{R_{\max}}{R_{average}}\right\}, \tag{5}$$

where F_{Buffer} is the buffer full flag that in the exemplary embodiment assumes a value of zero or one where one indicates the buffer full condition, R_{max} as described previously is the maximum transmission rate of the subscriber station, N_{rates} is the number of rates available for the subscriber station.

In control block 166, the subscriber station determines whether the maximum busy tone (b_1,b_2) has the value (1,0), which would indicate that at least one base station in its active set is heavily loaded. If the maximum busy tone has the value (1,0), the operation moves to control block 168, in which stochastic rate decrease is necessary. In control block 168, the subscriber station determines whether the computed rate R_{step3} is less than $R_{previous}$. If R_{step3} is less than $R_{previous}$, then in block 170 the current packet is transmitted at rate R_{step3}. If R_{step3} is greater than or equal to $R_{previous}$, then in block 172 the current packet is transmitted at a stochastically determined rate such that the packet is transmitted at rate $R_{previous}$ with probability p or is transmitted at the greater of $R_{previous}/2$ or R_{min} with probability 1-p. In the exemplary embodiment, the number p is again computed according to equation (5).

If the maximum busy tone does not have the value (1,0), the operation moves to block 176 which indicates that the at least one base station in the active set of the subscriber station is in an overload condition. In block 176, the transmission rate of the current packet is determined to be the greater of $R_{previous}/2$ or R_{min}.

II. Network Description

Referring to the figures, FIG. 2 represents the exemplary data communication system of the present invention which comprises multiple cells **200a - 200f**. Each cell **200** is serviced by a corresponding base station **202** or

base station **204**. Base stations **202** are base stations that are in active communication with subscriber station **206** and are said to make up the active set of subscriber station **206**. Base stations **204** are not in communication with subscriber station **206** but have signals with sufficient strength to be monitored by subscriber station **206** for addition to the active set if the strength of the received signals increases due to a change in the propagation path characteristics. Base stations **204** are said to make up the candidate set of subscriber station **206**.

In the exemplary embodiment, subscriber station **206** receives data information from at most one base station **202** on the forward link at each time slot, but it receives busy tone information from all base stations in the active set. Also, the subscriber station communicates with all base stations in the active set **202** on the reverse link. If the number of active base stations is more than one, the subscriber station **206** is in soft handoff. Subscriber stations **206**, especially those located near a cell boundary, can receive the pilot signals from multiple base stations **204** in the candidate set. If the pilot signal is above a predetermined threshold, subscriber station **206** can request that base station **204** be added to the active set of subscriber station **206**. In the exemplary embodiment, before the candidate base station **204** is added to the active set, there is typically no way for the subscriber station to monitor its busy tone. If a way is provided to monitor the busy tone of a candidate base station, then this busy tone enters the set inside of which a maximum is selected according to step **106** described above.

III. Forward Link Structure

A block diagram of the exemplary forward link architecture of the present invention is shown in FIG. 3A. The data is partitioned into data packets and provided to CRC encoder **312**. For each data packet, CRC encoder **312** generates frame check bits (e.g., the CRC parity bits) and inserts the code tail bits. The formatted packet from CRC encoder **312** comprises the data, the frame check and code tail bits, and other overhead bits which are described below. The formatted packet is provided to encoder **314** which, in the exemplary embodiment, encodes the data in accordance with a convolutional or turbo encoding format. The encoded packet from encoder **314** is provided to interleaver **316** which reorders the code symbols in the packet. The interleaved packet is provided to frame puncture element **318** which removes a fraction of the packet in the manner described below. The punctured packet is provided

to multiplier **320** which scrambles the data with the scrambling sequence from scrambler **322**. The output from multiplier **320** comprises the scrambled packet.

The scrambled packet is provided to variable rate controller **330** which demultiplexes the packet into K parallel inphase and quadrature channels, where K is dependent on the data rate. In the exemplary embodiment, the scrambled packet is first demultiplexed into the inphase (I) and quadrature (Q) streams. In the exemplary embodiment, the I stream comprises even indexed symbols and the Q stream comprises odd indexed symbol.

Each stream is further demultiplexed into K parallel channels such that the symbol rate of each channel is fixed for all data rates. The K channels of each stream are provided to Walsh cover element **332** which covers each channel with a Walsh function to provide orthogonal channels. The orthogonal channel data is provided to gain element **334** which scales the data to maintain a constant total-energy-per-chip (and hence constant output power) for all data rates. The scaled data from gain element **334** is provided to multiplexer (MUX) **360** which multiplexes the data with a preamble sequence. The output from MUX **360** is provided to multiplexer (MUX) **362** which multiplexes the traffic data, the power control bits, and the pilot data. The output of MUX **362** comprises the I Walsh channels and the Q Walsh channels.

The reverse link power control (RPC) bits are provided to symbol repeater **350** which repeats each RPC bit a predetermined number of times. The repeated RPC bits are provided to Walsh cover element **352** which covers the bits with the Walsh covers corresponding to the RPC indices. The covered bits are provided to gain element **354** which scales the bits prior to modulation so as to maintain a constant total transmit power.

In addition, a forward activity bit is provided to symbol repeater **350**. The forward activity bit alerts subscriber station **106** to a forthcoming blank frame in which the base station will not transmit forward link data. This transmission is made in order to allow subscriber station **106** to make a better estimate of the C/I of the signal from base stations **102**. The repeated versions of the forward activity bit are Walsh covered in Walsh cover element **352** so as to be orthogonal to the Walsh covered power control bits. The covered bits are provided to gain element **354** which scales the bits prior to modulation so as to maintain a constant total transmit power.

In addition, a busy tone is provided to symbol repeater **350**. The busy tone alerts subscriber station **206** to a reverse link loading condition. In an exemplary embodiment, the busy tone is a single bit indicative of the reverse link being fully loaded or having spare capacity. In the preferred embodiment, the busy tone is a two bit signal indicative of a request by base stations **202** for

subscriber stations **206** in its coverage area to either deterministically increase or decrease the rate of their reverse link transmissions, or to stochastically increase or decrease the rate of their reverse link transmissions. The repeated versions of the busy tone is Walsh covered in Walsh cover element **352** so as to be orthogonal to the Walsh covered power control bits and forward activity bit. The covered bit is provided to gain element **354** which scales the bits prior to modulation so as to maintain a constant total transmit power.

The pilot data comprises a sequence of all zeros (or all ones) which is provided to multiplier **356**. Multiplier **356** covers the pilot data with Walsh code W_0. Since Walsh code W_0 is a sequence of all zeros, the output of multiplier **356** is the pilot data. The pilot data is time multiplexed by MUX **362** and provided to the I Walsh channel which is spread by the short PN_I code within complex multiplier **366** (see FIG. 3B). In the exemplary embodiment, the pilot data is not spread with the long PN code, which is gated off during the pilot burst by MUX **376**, to allow reception by all subscriber stations **376**. The pilot signal is thus an unmodulated BPSK signal.

A block diagram of the exemplary modulator used to modulate the data is illustrated in FIG. 3B. The I Walsh channels and Q Walsh channels are provided to summers **364a** and **364b**, respectively, which sum the K Walsh channels to provide the signals I_{sum} and Q_{sum}, respectively. The I_{sum} and Q_{sum} signals are provided to complex multiplier **366**. Complex multiplier **366** also receives the PN_I and PN_Q signals from multipliers **378a** and **378b**, respectively, and multiplies the two complex inputs in accordance with the following equation :

$$\begin{aligned}(I_{mult} + jQ_{mult}) &= (I_{sum} + jQ_{sum}) \bullet (PN\_I + jPN\_Q) \\ &= (I_{sum} \bullet PN\_I - Q_{sum} \bullet PN\_Q) + j(I_{sum} \bullet PN\_Q + Q_{sum} \bullet PN\_I) \quad , \end{aligned} \tag{6}$$

where I_{mult} and Q_{mult} are the outputs from complex multiplier **366** and j is the complex representation. The I_{mult} and Q_{mult} signals are provided to filters **368a** and **368b**, respectively, which filter the signals. The filtered signals from filters **368a** and **368b** are provided to multipliers **370a** and **370b**, respectively, which multiply the signals with the inphase sinusoid $COS(w_c t)$ and the quadrature sinusoid $SIN(w_c t)$, respectively. The I modulated and Q modulated signals are provided to summer **372** which sums the signals to provide the forward modulated waveform S(t).

In the exemplary embodiment, the data packet is spread with the long PN code and the short PN codes. The long PN code scrambles the packet such that only the subscriber station **106** for which the packet is destined is able to descramble the packet. In the exemplary embodiment, the pilot and power control bits and the control channel packet are spread with the short PN codes but not the long PN code to allow all subscriber stations **106** to receive these bits. The long PN sequence is generated by long code generator **374** and provided to multiplexer (MUX) **376**. The long PN mask determines the offset of the long PN sequence and is uniquely assigned to the destination subscriber station **106**. The output from MUX **376** is the long PN sequence during the data portion of the transmission and zero otherwise (e.g. during the pilot and power control portion). The gated long PN sequence from MUX **376** and the short PN_I and PN_Q sequences from short code generator **380** are provided to multipliers **378a** and **378b**, respectively, which multiply the two sets of sequences to form the PN_I and PN_Q signals, respectively. The PN_I and PN_Q signals are provided to complex multiplier **366**.

The block diagram of the exemplary traffic channel shown in FIGS. 3A and 3B is one of numerous architectures which support data encoding and modulation on the forward link. Other architectures, such as the architecture for the forward link traffic channel in the CDMA system which conforms to the IS-95 standard, can also be utilized and are within the scope of the present invention.

IV. Forward Link Frame Structure

A diagram of the exemplary forward link frame structure of the present invention is illustrated in FIG. 4A. The traffic channel transmission is partitioned into frames which, in the exemplary embodiment, are defined as the length of the short PN sequences or 26.67 msec. Each frame can carry control channel information addressed to all subscriber stations **106** (control channel frame), traffic data addressed to a particular subscriber station **106** (traffic frame), or can be empty (idle frame). The content of each frame is determined by the scheduling performed by the transmitting base station **102**. In the exemplary embodiment, each frame comprises 16 time slots, with each time slot having a duration of 1.667 msec. A time slot of 1.667 msec is adequate to enable subscriber station **106** to perform the C/I measurement of the forward link signal. A time slot of 1.667 msec also represents a sufficient amount of time for efficient packet data transmission.

In the exemplary embodiment, each forward link data packet comprises 1024 or 2048 bits. Thus, the number of time slots required to transmit each data packet is dependent on the data rate and ranges from 16 time slots for a 38.4 Kbps rate to 1 time slot for a 1.2288 Mbps rate.

An exemplary diagram of the forward link slot structure of the present invention is shown in FIG. 4B. In the exemplary embodiment, each slot comprises three of the four time multiplexed channels, the traffic channel, the control channel, the pilot channel, and the overhead control channel. In the exemplary embodiment, the pilot signal is transmitted in two bursts and the overhead control channel is transmitted on either side of the second pilot burst. The traffic data is carried in three portions of the slot (**402a**, **402b** and **402c**).

The first pilot burst **406a** is time multiplexed into the first half of the slot by multiplexer **362**. The second pilot burst **406b** is time multiplexed into the second half of the slot. On either side of the second pilot burst **406b**, overhead channel data **408** including the forward activity bit, the busy tones and the power control bits are multiplexed into the slot.

In the exemplary embodiment, the busy tone is a two bit signal, and the busy tone is only set once per frame. In the exemplary embodiment, the busy tone is interleaved among the slots of a frame such that the even slots carry the first bit of the busy tone and the odd slots carry the second bit of the busy tone. Other ways to interleave the busy tone bits are obvious to the skilled in the art and are within the scope of the present invention.

V. Subscriber Station Architecture

FIG. 5 illustrates the exemplary subscriber station of the present invention. Buffer **524** provides a signal indicative of the amount of data queued for transmission to rate allocation control processor **522**. Rate allocation control processor **522** selects the rate based on the buffer state as described with respect to step **100** above. In the exemplary embodiment, buffer **524** is divided into two parts. A first part of buffer **524** stores new data for transmission. A second part of buffer **524** stores data for retransmission. In the exemplary embodiment, rate control processor **522** selects the rate in accordance with a buffer full flag that is set in accordance with the new data to be transmitted.

Transmitter **528** is responsible for upconverting, filtering and amplifying the reverse link signal for transmission. Transmitter **528** provides a signal to rate allocation control processor **522** indicative of the amount of power headroom available for transmission of the current data packet. In response to this signal rate allocation control processor **522** determines the adjustment to

the rate of transmission of the next packet as described with respect to block **102** above.

Forward link signals are received by subscriber station **206** at antenna **500** and provided through duplexer **502** to receiver **504**. Receiver **504** downconverts, filters and amplifies the received signal and provides the signal to pilot energy calculator **506**. Pilot energy calculator **506** calculates the energy of the pilot signals received from active set base stations **202** and candidate set base stations **204**.

The received signals are provided to pilot despreader **510**, which despreads the pilot signals in accordance with control signals from search controller **508**. In the exemplary embodiment, search controller **508** provides a PN offset of a candidate set or active set base station to pilot despreader **510** which in response despreads the pilot signal from a candidate set base station **204** or active set base station **206**.

The despread pilot symbols are provided to squaring element **512** which computes the energy of the symbols and provides the symbol energy values to accumulator **514**. Accumulator **514** accumulates the energies over the time interval of the pilot burst and provides the pilot burst energy to rate allocation element **522**. In response to the pilot burst energies from the candidate set base stations (Ec/Io) and the pilot burst energies from active set base station (Ea/Io), rate allocation control processor **522** computes the candidate set protection adjustment to the selected rate as described with respect to block **104** above.

The received signals are also provided to busy tone demodulators **516**. Busy tone demodulators **516** demodulate the busy tone values for each active set base station **202** and provide the busy tone values for each base station to rate allocation control processor **522**. In response rate allocation control processor **522** selects maximum busy tone as described in **106** above, and calculates the rate of the transmission as described with respect to **108** above.

Once the rate of transmission has been determined by rate allocation control processor **522**, a signal indicative of the selected rate is provided to buffer **524**, modulator **526** and transmitter **528**. Buffer **524** outputs a block of data in accordance with the selected transmission rate to modulator **526**. Modulator **526** modulates the signal in accordance with the selected data rate and provides the modulated data to transmitter **528**. Transmitter amplifies the signal in accordance with selected transmission rate and provides the signal through duplexer **502** for transmission through antenna **500**. The rate selected can be indicated to the active base stations through a reverse link message.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

I CLAIM:

CLAIMS

1. A method for determining reverse link transmission rate at a subscriber station comprising the steps of:

receiving a busy tone signal indicative of the reverse link loading from each base station in the active set of said station;

selecting one of said busy tone signals; and

determining said reverse link transmission rate in accordance with said selected one of said busy tone signals.

2. The method of Claim 1 wherein said busy tones signals are indicated by an integer value where the loading indicated increases with the value of said integer value and wherein said step of selecting one of said busy tone signals comprises selecting the busy tone signal with the greatest value.

3. The method of Claim 2 wherein said busy tone is transmitted as a two bit number and wherein

(0,0) indicates a scarcely loaded base station;

(0,1) indicates a stable base station;

(1,0) indicates a heavily loaded base station; and

(1,1) indicates a base station overload condition.

4. A method for determining reverse link transmission rate at a subscriber station comprising the steps of:

selecting an initial rate in accordance with the amount of data queued to be transmitted by said subscriber station; and

adjusting said initial rate in accordance with at least one received busy tone value.

5. The method of Claim 4 further comprising the step of:

determining the amount of power headroom in the subscriber station;

adjusting said initial rate in accordance with said power headroom to provide a second adjusted rate; and

wherein said step of adjusting said initial rate is performed on said second adjusted rate.

6. The method of Claim 4 further comprising the step of:

determining an energy difference metric in accordance with signal strengths from candidate base stations and active set base stations;

adjusting said initial rate in accordance with said energy difference metric to provide a second adjusted rate; and

wherein said step of adjusting said initial rate is performed on said second adjusted rate.

7. The method of Claim 5 further comprising the step of:

determining an energy difference metric in accordance with signal strengths from candidate base stations and active set base stations;

adjusting said second adjusted rate in accordance with said energy difference metric to provide a third adjusted rate; and

wherein said step of adjusting said initial rate is performed on said third adjusted rate.

8. The method of Claim 4 wherein said step of selecting an initial rate in accordance with the amount of data queued to be transmitted by said subscriber station, comprises the steps of:

determining whether the amount of data queued to be transmitted can be carried in a packet transmitted at the predetermined maximum data rate;

setting said initial rate to the predetermined maximum rate when the amount of data queued to be transmitted exceeds the amount of information that can be carried in a packet transmitted at the predetermined maximum data rate;

setting said initial rate to a second rate which is less than said predetermined maximum rate when the amount of data queued to be transmitted is less than the amount of information that can be carried in a packet transmitted at the predetermined maximum data rate; and

setting said initial rate to the less of the current value of the initial rate or twice the rate at which a previous frame was transmitted.

9. The method of Claim 5 wherein said step of adjusting said initial rate in accordance with said power headroom to provide a second adjusted rate, comprises the steps of:

selecting the maximum rate capable of reliable transmission by said subscriber station in accordance with said power headroom; and

selecting the lesser of the initial rate and said maximum rate capable of reliable transmission by said subscriber station as said second adjusted rate.

10. A method for selecting a data rate for reverse link transmissions, comprising the steps of:

selecting an initial rate in accordance with the amount of data in a transmission buffer;

modifying said initial rate in accordance with a power headroom value to provide a first adjusted rate;

modifying said first adjusted rate in accordance with a candidate set protection value to provide a second adjusted rate; and

modifying said second adjusted rate in accordance with a received busy tone value to provide said selected reverse link transmission rate.

11. The method of Claim 10 wherein said step of selecting an initial rate, comprises the steps of:

determining whether the amount of data queued to be transmitted can be carried in a packet transmitted at the predetermined maximum data rate;

setting said initial rate to the predetermined maximum rate when the amount of data queued to be transmitted exceeds the amount of information that can be carried in a packet transmitted at the predetermined maximum data rate;

setting said initial rate to a second rate which is less than said predetermined maximum rate when the amount of data queued to be transmitted is less than the amount of information that can be carried in a packet transmitted at the predetermined maximum data rate; and

setting said initial rate to the less of the current value of the initial rate or twice the rate at which a previous frame was transmitted.

12. The method of Claim 10 wherein said step of selecting an initial rate, comprises the steps of:

determining whether said amount of data in said buffer exceeds a predetermined amount; and

setting a flag when said amount of data in said buffer exceeds a predetermined amount.

13. The method of Claim 10 wherein said step of selecting an initial rate, comprises the steps of:

determining whether said amount of data in said buffer exceeds a predetermined amount; and

setting a flag when said amount of data in said buffer exceeds a predetermined amount.

14. The method of Claim 10 wherein said step of modifying said initial rate in accordance with a power headroom value to provide a first adjusted rate, comprises:

determining the maximum power capable of being transmitted by said subscriber station; and

selecting the maximum rate capable of being transmitted at or below said maximum power capable of being transmitted by said subscriber station.

15. The method of Claim 14 wherein said step of selecting the maximum rate comprises the steps of:

determining whether said subscriber station is in soft handoff; and

wherein said step of selecting the maximum rate is performed in accordance with said determination as to determining whether said subscriber station is in soft handoff.

16. The method of Claim 14 wherein said step of selecting the maximum rate comprises the steps of:

determining distance between said subscriber station and an active set base station; and

wherein said step of selecting the maximum rate is performed in accordance with determining distance between said subscriber station and an active set base station.

17. The method of Claim 14 wherein said step of selecting the maximum rate comprises the steps of:

determining the speed of said subscriber station; and

wherein said step of selecting the maximum rate is performed in accordance with the speed of said subscriber station.

18. The method of Claim 14 wherein said step of modifying said first adjusted rate in accordance with a candidate set protection value to provide a second adjusted rate, comprising the steps of:

measuring the signal energy of at least one candidate set base station;

measuring the signal energy of at least one active set base station;

computing said candidate set protection value in accordance with said signal energy of at least one active set base station and said signal energy of at least one candidate set base station.

19. The method of Claim 18 wherein said step of computing said candidate set protection value in accordance with said signal energy of at least one active set base station and said signal energy of at least one candidate set base station, comprising the steps of:

summing the energies of said signal energy of at least one active set base station to provide a summed active set energy;

summing the energies of said signal energy of at least one candidate set base station to provide a summed candidate set energy;

and wherein said step of computing said candidate set protection value is performed in accordance with the difference between said summed active set energy and said summed active set energy.

20. The method of Claim 18 wherein said step of computing said candidate set protection value in accordance with said signal energy of at least one active set base station and said signal energy of at least one candidate set base station, comprising the steps of:

selecting a minimum energy active set base station of said signal energy of at least one active set base station;

selecting a maximum energy candidate set base station of said signal energy of at least one candidate set base station;

and wherein said step of computing said candidate set protection value is performed in accordance with the difference between the signal energy of said minimum energy active set base station and the signal energy of said maximum energy candidate set base station.

21. The method of Claim 18 wherein said step of computing said candidate set protection value in accordance with said signal energy of at least one active set base station and said signal energy of at least one candidate set base station, comprising the steps of:

selecting a minimum energy active set base station of said signal energy of at least one active set base station;

summing the energies of said signal energy of at least one candidate set base station to provide a summed candidate set energy; and

wherein said step of computing said candidate set protection value is performed in accordance with the difference between the signal energy of said minimum energy active set base station and said summed active set energy.

22. The method of Claim 18 wherein said step of computing said candidate set protection value in accordance with said signal energy of at least

one active set base station and said signal energy of at least one candidate set base station, comprising the steps of:

selecting a maximum energy active set base station of said signal energy of at least one active set base station;

selecting a maximum energy candidate set base station of said signal energy of at least one candidate set base station;

and wherein said step of computing said candidate set protection value is performed in accordance with the difference between the signal energy of said maximum energy active set base station and the signal energy of said maximum energy candidate set base station.

23. The method of Claim 10 wherein said step of modifying said second adjusted rate in accordance with a received busy tone value to provide said selected reverse link transmission rate is performed in accordance with a stochastic process.

24. The method of Claim 23 wherein stochastic process is determined in accordance with the average number rate of transmission over a predetermined prior interval.

25. The method of Claim 23 wherein stochastic process is determined in accordance with the a buffer capacity flag.

26. The method of Claim 25 wherein stochastic process is determined in accordance with the a buffer capacity flag.

27. The method of Claim 26 wherein the probability of increasing the transmission rate (p) is given by:

$$p = \min\left\{1, \frac{1 + F_{Buffer}/2}{N_{rates}} \log_2 \frac{R_{\max}}{R_{average}}\right\},$$

where R average is the average data rate in a predetermined number of previous transmissions, F_{Buffer} is the buffer full flag that in the exemplary embodiment assumes a value of zero or one where one indicates the buffer full condition, R_{max} as described previously is the maximum transmission rate of the subscriber station, N_{Rates} is the number of rates available for the subscriber station.

28. A subscriber station for transmitting high rate digital data comprising:

receiver for receiving a busy tone signal indicative of the reverse link loading from each base station in the active set of said station; and

control processor for selecting one of said busy tone signals and determining said reverse link transmission rate in accordance with said selected one of said busy tone signals.

29. The subscriber station of Claim 28 wherein said busy tones signals are indicated by an integer value where the loading indicated increases with the value of said integer value and wherein said step of selecting one of said busy tone signals comprises selecting the busy tone signal with the greatest value.

30. The method of Claim 29 wherein said busy tone is received as a two bit number and wherein

(0,0) indicates a scarcely loaded base station;

(0,1) indicates a stable base station;

(1,0) indicates a heavily loaded base station; and

(1,1) indicates a base station overload condition.

31. A subscriber station for transmitting high speed digital data comprising:

a buffer for storing data for transmission by said subscriber station;

receiver for receiving a busy tone signal indicative of the reverse link loading from each base station in the active set of said station; and

control processor for selecting one of said busy tone signals and determining said reverse link transmission rate in accordance with said selected one of said busy tone signals and the amount of data in said buffer.

32. The subscriber station of Claim 31 further comprising:

wherein said control processor is further for determining the amount of power headroom in the subscriber station and for determining said transmission rate in accordance with said power.

33. The subscriber station of Claim 31 wherein said control processor is further for determining an energy difference metric in accordance with signal strengths from candidate base stations and active set base stations and for

determining said transmission rate in accordance with said energy difference metric to provide a second adjusted rate.

34. The subscriber station of Claim 32 wherein said control processor is further for determining an energy difference metric in accordance with signal strengths from candidate base stations and active set base stations and for determining said transmission rate in accordance with said energy difference metric to provide a second adjusted rate.

35. The subscriber station of Claim 31 wherein said control processor determines whether the amount of data queued to be transmitted can be carried in a packet transmitted at the predetermined maximum data rate selecting said transmission rate to a predetermined maximum rate when the amount of data queued to be transmitted exceeds the amount of information that can be carried in a packet transmitted at the predetermined maximum data rate and setting said initial rate to a second rate which is less than said predetermined maximum rate when the amount of data queued to be transmitted is less than the amount of information that can be carried in a packet transmitted at the predetermined maximum data rate.

36. The subscriber station of Claim 32 wherein said control processor selects the maximum rate capable of reliable transmission by said subscriber station in accordance with said power headroom and selects the lesser of the initial rate and said maximum rate capable of reliable transmission by said subscriber station as said second adjusted rate.

37. A subscriber station for transmitting data at a selected rate of a set of possible rates, comprising:

buffer for storing an amount of data to be transmitted by said subscriber station;

receiver subsystem for receiving a busy tone signal indicative of a busy tone value;

control processor for selecting an initial rate in accordance with the amount of data in a transmission buffer, modifying said initial rate in accordance with a power headroom value to provide a first adjusted rate, modifying said first adjusted rate in accordance with a candidate set protection value to provide a second adjusted rate, and modifying said second adjusted rate in accordance with a received busy tone value to provide said selected reverse link transmission rate; and

transmitter for transmitting data at said selected data rate.

38. The subscriber station of Claim 37 wherein said control processor determines whether the amount of data queued to be transmitted can be carried in a packet transmitted at the predetermined maximum data rate, sets said initial rate to the predetermined maximum rate when the amount of data queued to be transmitted exceeds the amount of information that can be carried in a packet transmitted at the predetermined maximum data rate, sets said initial rate to a second rate which is less than said predetermined maximum rate when the amount of data queued to be transmitted is less than the amount of information that can be carried in a packet transmitted at the predetermined maximum data rate and sets said initial rate to the less of the current value of the initial rate or twice the rate at which a previous frame was transmitted.

39. The method of Claim 37 wherein said control processor determines whether said amount of data in said buffer exceeds a predetermined amount and sets a flag when said amount of data in said buffer exceeds a predetermined amount.

40. The subscriber station of Claim 38 wherein said control processor determines whether said amount of data in said buffer exceeds a predetermined amount sets a flag when said amount of data in said buffer exceeds a predetermined amount.

41. The subscriber station of Claim 37 wherein said control processor determines the maximum power capable of being transmitted by said subscriber station and selects the maximum rate capable of being transmitted at or below said maximum power capable of being transmitted by said subscriber station.

42. The subscriber station of Claim 41 wherein said control processor determines whether said subscriber station is in soft handoff and wherein said subscriber station selects the maximum rate is performed in accordance with said determination as to whether said subscriber station is in soft handoff.

43. The method of Claim 41 wherein said control processor determines a distance between said subscriber station and an active set base station and selects the maximum rate is performed in accordance with

determining distance between said subscriber station and an active set base station.

44. The subscriber station of Claim 41 wherein said control processor determines the speed of said subscriber station and selects the maximum in accordance with the speed of said subscriber station.

45. The subscriber station of Claim 41 wherein said control processor estimates the signal energy of at least one candidate set base station, estimates the signal energy of at least one active set base station, and computes said candidate set protection value in accordance with said signal energy of at least one active set base station and said signal energy of at least one candidate set base station.

46. The subscriber station of Claim 45 wherein said control processor sums the energies of said signal energy of at least one active set base station to provide a summed active set energy, sums the energies of said signal energy of at least one candidate set base station to provide a summed candidate set energy, computes said candidate set protection value is performed in accordance with the difference between said summed active set energy and said summed active set energy.

47. The subscriber station of Claim 45 wherein said control processor selects a minimum energy active set base station of said signal energy of at least one active set base station, selects a maximum energy candidate set base station of said signal energy of at least one candidate set base station, and computes said candidate set protection value is performed in accordance with the difference between the signal energy of said minimum energy active set base station and the signal energy of said maximum energy candidate set base station.

48. The subscriber station of Claim 45 wherein said control processor selects a minimum energy active set base station of said signal energy of at least one active set base station, sums the energies of said signal energy of at least one candidate set base station to provide a summed candidate set energy, and computes said candidate set protection value is performed in accordance with the difference between the signal energy of said minimum energy active set base station and said summed active set energy.

49. The subscriber station of Claim 45 wherein said control processor selects a maximum energy active set base station of said signal energy of at least one active set base station, selects a maximum energy candidate set base station of said signal energy of at least one candidate set base station and computes said candidate set protection value is performed in accordance with the difference between the signal energy of said maximum energy active set base station and the signal energy of said maximum energy candidate set base station.

50. The subscriber station of Claim 37 wherein control processor selects said transmission rate in accordance with a stochastic process.

51. The subscriber station of Claim 50 wherein stochastic process is determined in accordance with the average number rate of transmission over a predetermined prior interval.

52. The subscriber station of Claim 50 wherein stochastic process is determined in accordance with the a buffer capacity flag.

53. The method of Claim 521 wherein stochastic process is determined in accordance with the a buffer capacity flag.

54. The method of Claim 53 wherein the probability of increasing the transmission rate (p) is given by:

$$p = \min\left\{1, \frac{1 + F_{Buffer}/2}{N_{rates}} \log_2 \frac{R_{\max}}{R_{average}}\right\},$$

where R average is the average data rate in a predetermined number of previous transmissions, F_{Buffer} is the buffer full flag that in the exemplary embodiment assumes a value of zero or one where one indicates the buffer full condition, R_{max} as described previously is the maximum transmission rate of the subscriber station, N_{Rates} is the number of rates available for the subscriber station.

55. A base station comprising:

means of measuring reverse link loading; and

means for transmitting a busy tone signal indicative of said reverse link loading.

56. The base station of of Claim 55 wherein said busy tone signal is transmitted as a two bit number and wherein

(0,0) indicates a scarcely loaded base station;

(0,1) indicates a stable base station;

(1,0) indicates a heavily loaded base station; and

(1,1) indicates a base station overload condition.

57. The base station of Claim 56 wherein said base station is a CDMA base station.

58. The base station of Claim 57 wherein busy tone signal is time multiplexed into a CDMA signal.

59. The base station of Claim 56 wherein said base station is further for transmitting a signal indicative of a maximum permissible reverse link transmission rate.

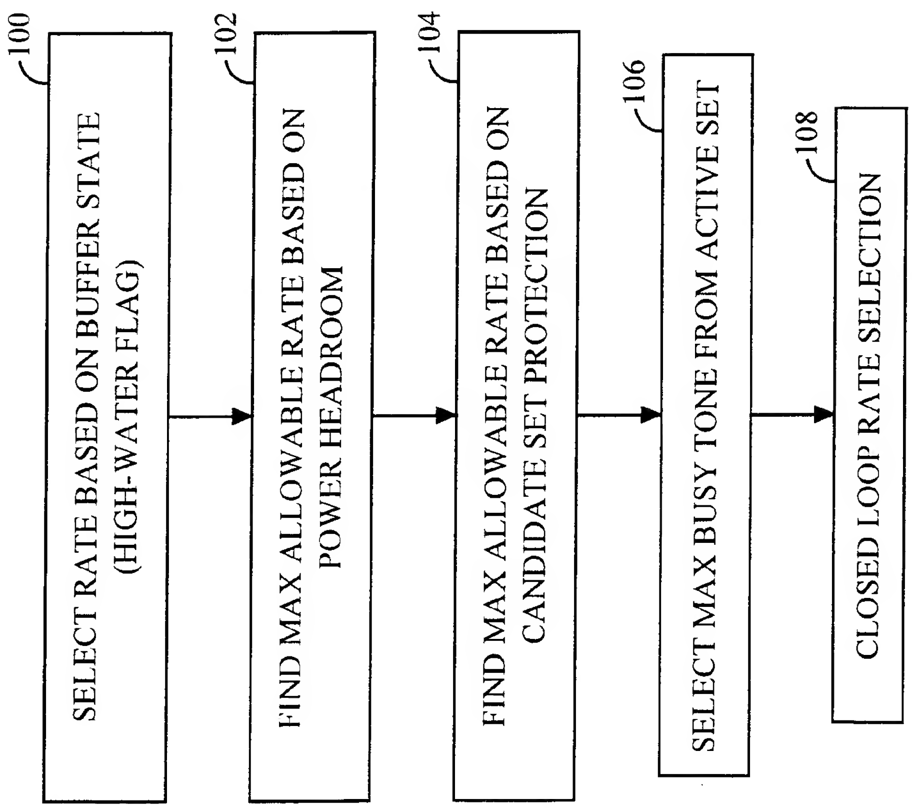

100
SELECT RATE BASED ON BUFFER STATE (HIGH-WATER FLAG)
102
FIND MAX ALLOWABLE RATE BASED ON POWER HEADROOM
104
FIND MAX ALLOWABLE RATE BASED ON CANDIDATE SET PROTECTION
106
SELECT MAX BUSY TONE FROM ACTIVE SET
108
CLOSED LOOP RATE SELECTION

FIG. 1A

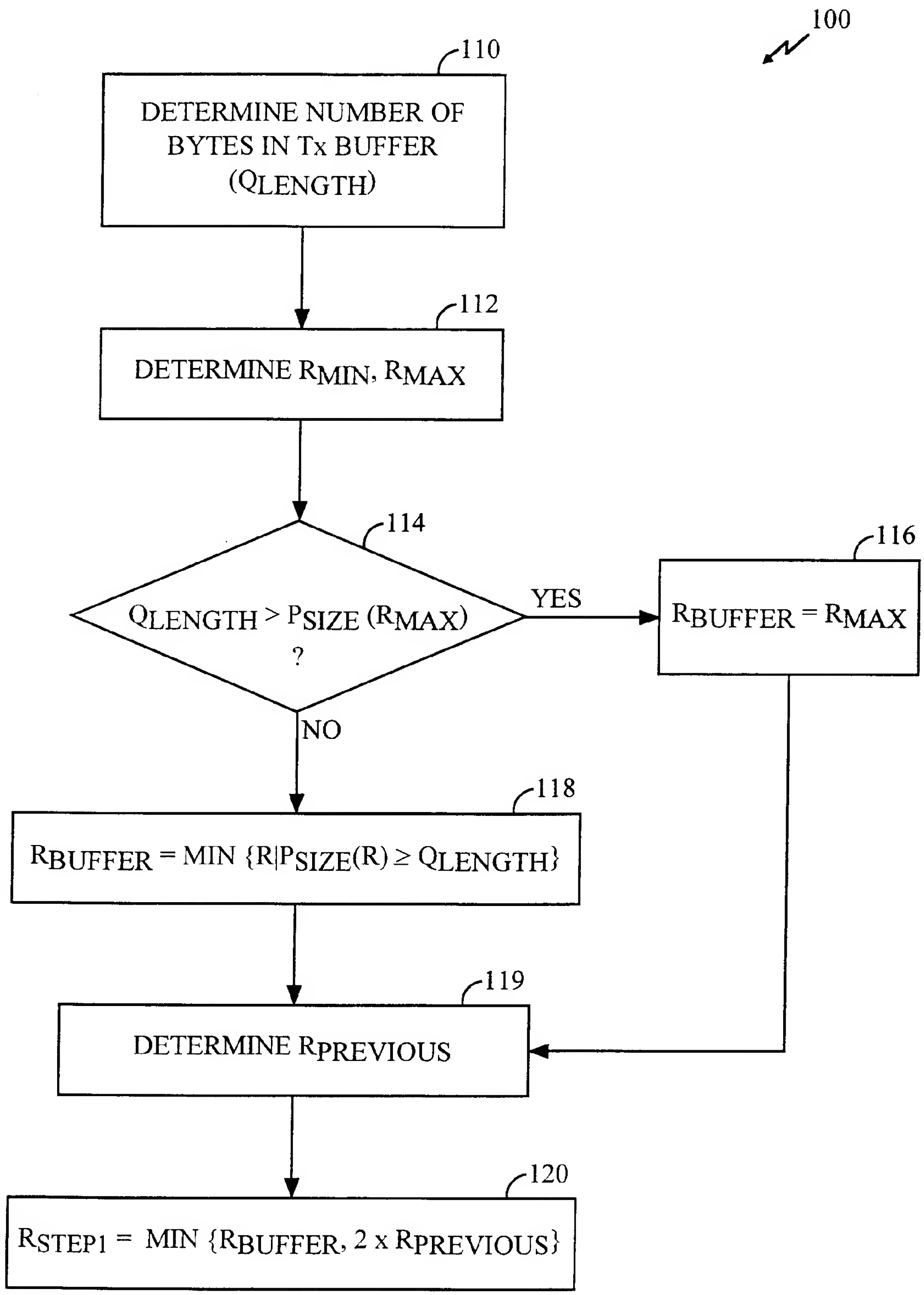

100
110
DETERMINE NUMBER OF BYTES IN Tx BUFFER (Q_{LENGTH})
112
DETERMINE R_{MIN}, R_{MAX}
114
$Q_{LENGTH} > P_{SIZE}(R_{MAX})$?
YES
116
$R_{BUFFER} = R_{MAX}$
NO
118
$R_{BUFFER} = MIN\{R \mid P_{SIZE}(R) \geq Q_{LENGTH}\}$
119
DETERMINE $R_{PREVIOUS}$
120
$R_{STEP1} = MIN\{R_{BUFFER}, 2 \times R_{PREVIOUS}\}$

FIG. 1B

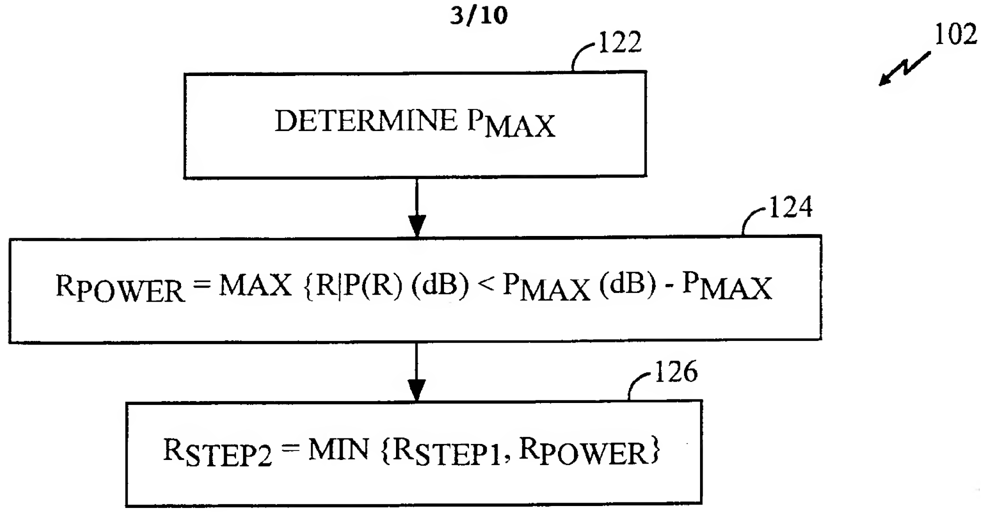

102
122
DETERMINE P_{MAX}
124
$R_{POWER} = MAX \{R|P(R) (dB) < P_{MAX} (dB) - P_{MAX}$
126
$R_{STEP2} = MIN \{R_{STEP1}, R_{POWER}\}$

FIG. 1C

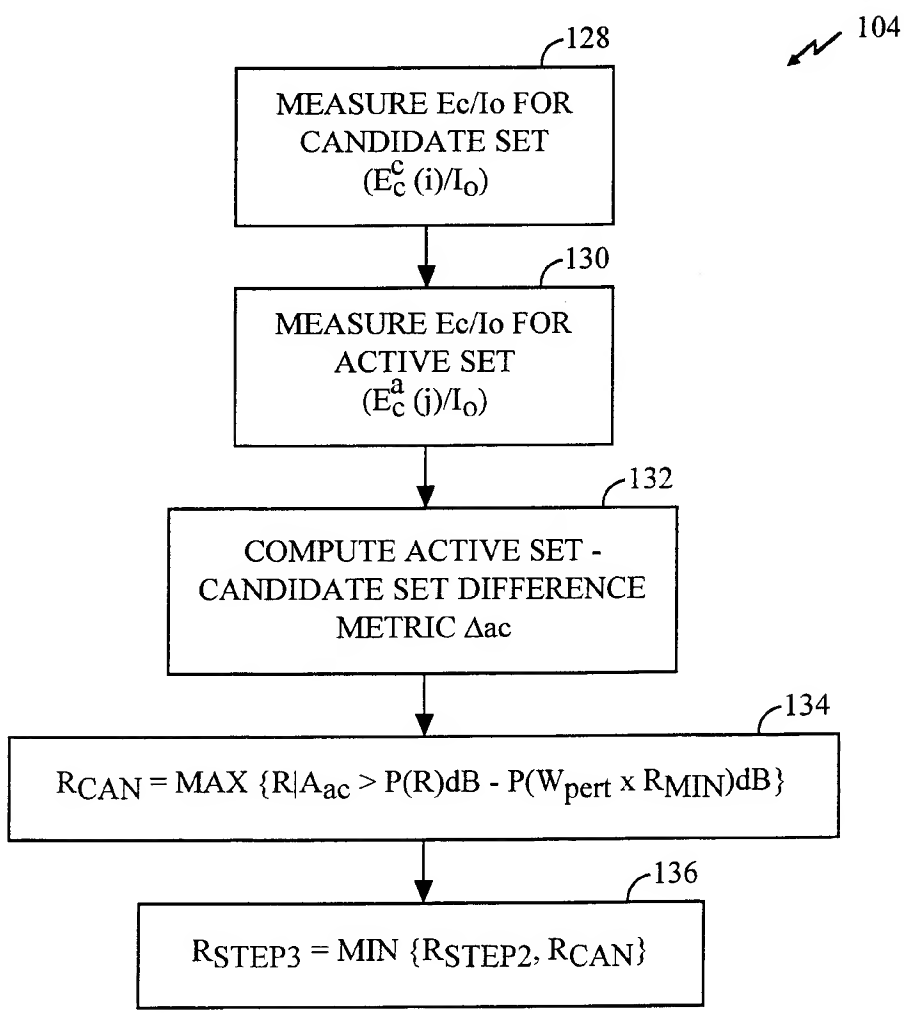

104
128
MEASURE Ec/Io FOR CANDIDATE SET (E_c^c (i)/I_o)
130
MEASURE Ec/Io FOR ACTIVE SET (E_c^a (j)/I_o)
132
COMPUTE ACTIVE SET - CANDIDATE SET DIFFERENCE METRIC Δac
134
$R_{CAN} = MAX \{R|A_{ac} > P(R)dB - P(W_{pert} \times R_{MIN})dB\}$
136
$R_{STEP3} = MIN \{R_{STEP2}, R_{CAN}\}$

FIG. 1D

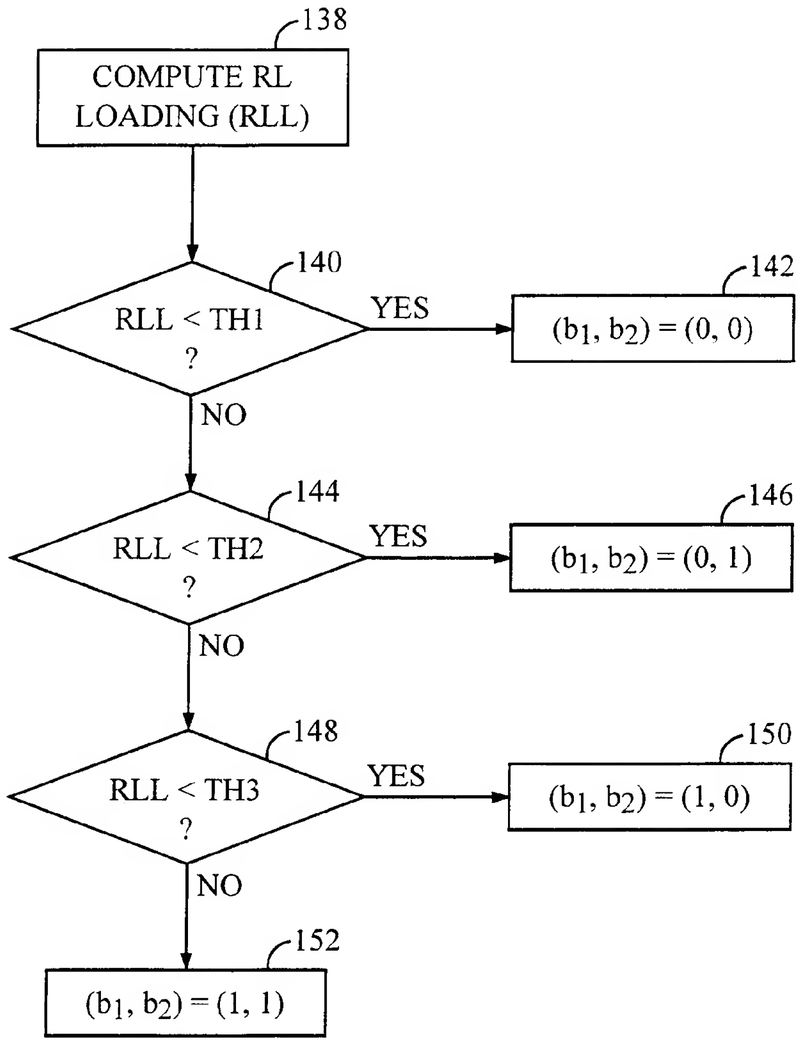

138
COMPUTE RL LOADING (RLL)
140
RLL < TH1 ?
YES
142
$(b_1, b_2) = (0, 0)$
NO
144
RLL < TH2 ?
YES
146
$(b_1, b_2) = (0, 1)$
NO
148
RLL < TH3 ?
YES
150
$(b_1, b_2) = (1, 0)$
NO
152
$(b_1, b_2) = (1, 1)$

FIG. 1E

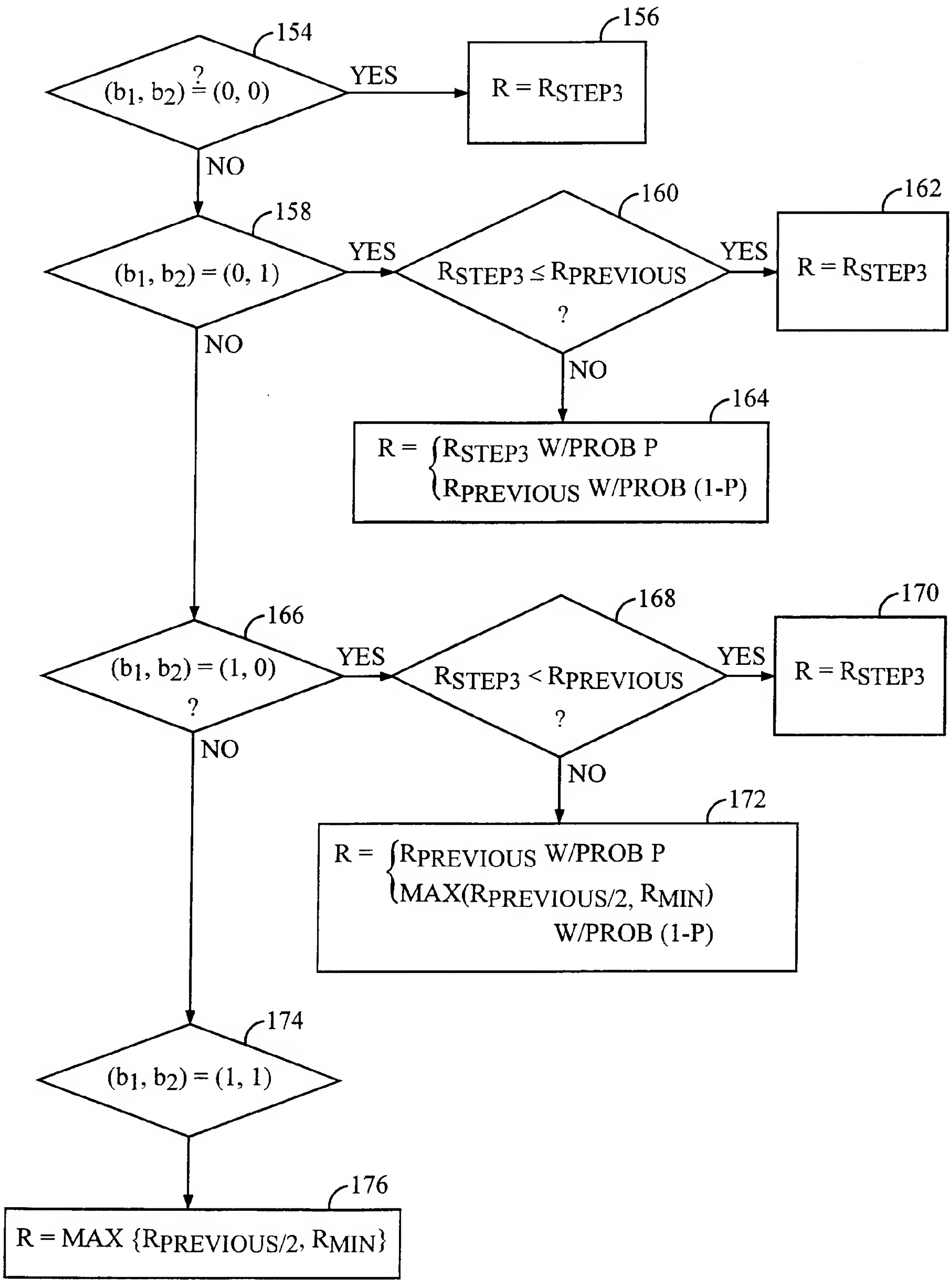

154
$(b_1, b_2) \stackrel{?}{=} (0, 0)$
YES
156
$R = R_{STEP3}$
NO
158
$(b_1, b_2) = (0, 1)$
YES
160
$R_{STEP3} \leq R_{PREVIOUS}$?
YES
162
$R = R_{STEP3}$
NO
NO
164
$R = \begin{cases} R_{STEP3} \text{ W/PROB P} \\ R_{PREVIOUS} \text{ W/PROB (1-P)} \end{cases}$
166
$(b_1, b_2) = (1, 0)$?
YES
168
$R_{STEP3} < R_{PREVIOUS}$?
YES
170
$R = R_{STEP3}$
NO
NO
172
$R = \begin{cases} R_{PREVIOUS} \text{ W/PROB P} \\ MAX(R_{PREVIOUS/2}, R_{MIN}) \text{ W/PROB (1-P)} \end{cases}$
174
$(b_1, b_2) = (1, 1)$
176
$R = MAX \{R_{PREVIOUS/2}, R_{MIN}\}$

FIG. 1F

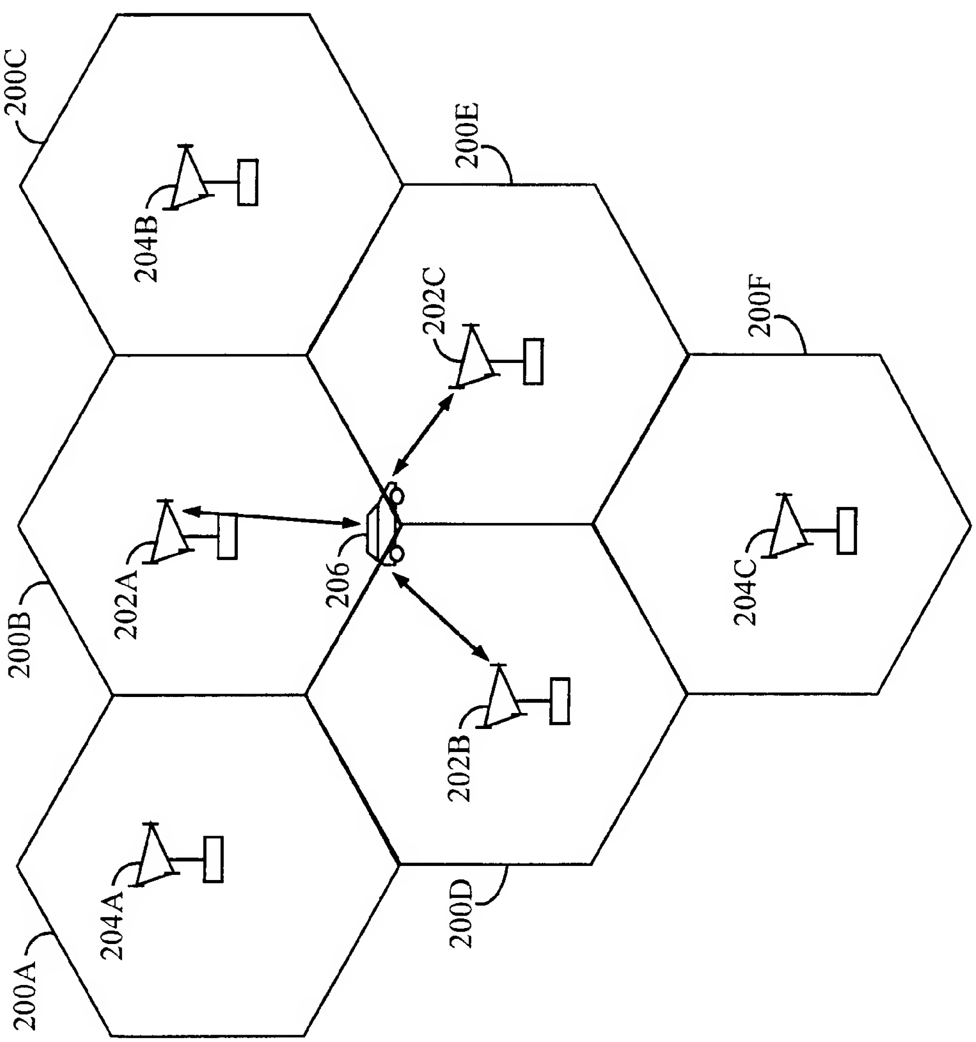

200A
200B
200C
200D
200E
200F
202A
202B
202C
204A
204B
204C
206

FIG. 2

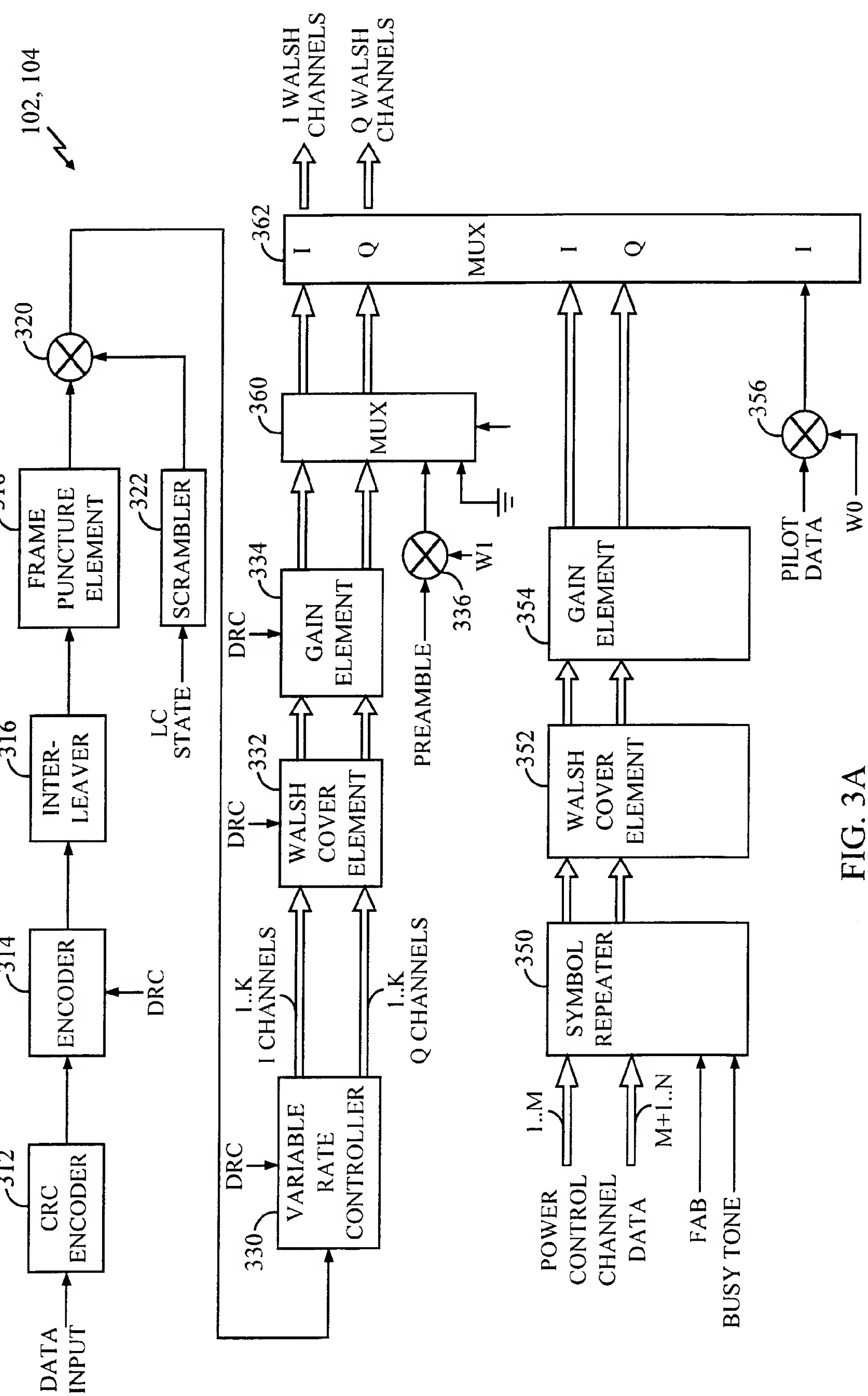
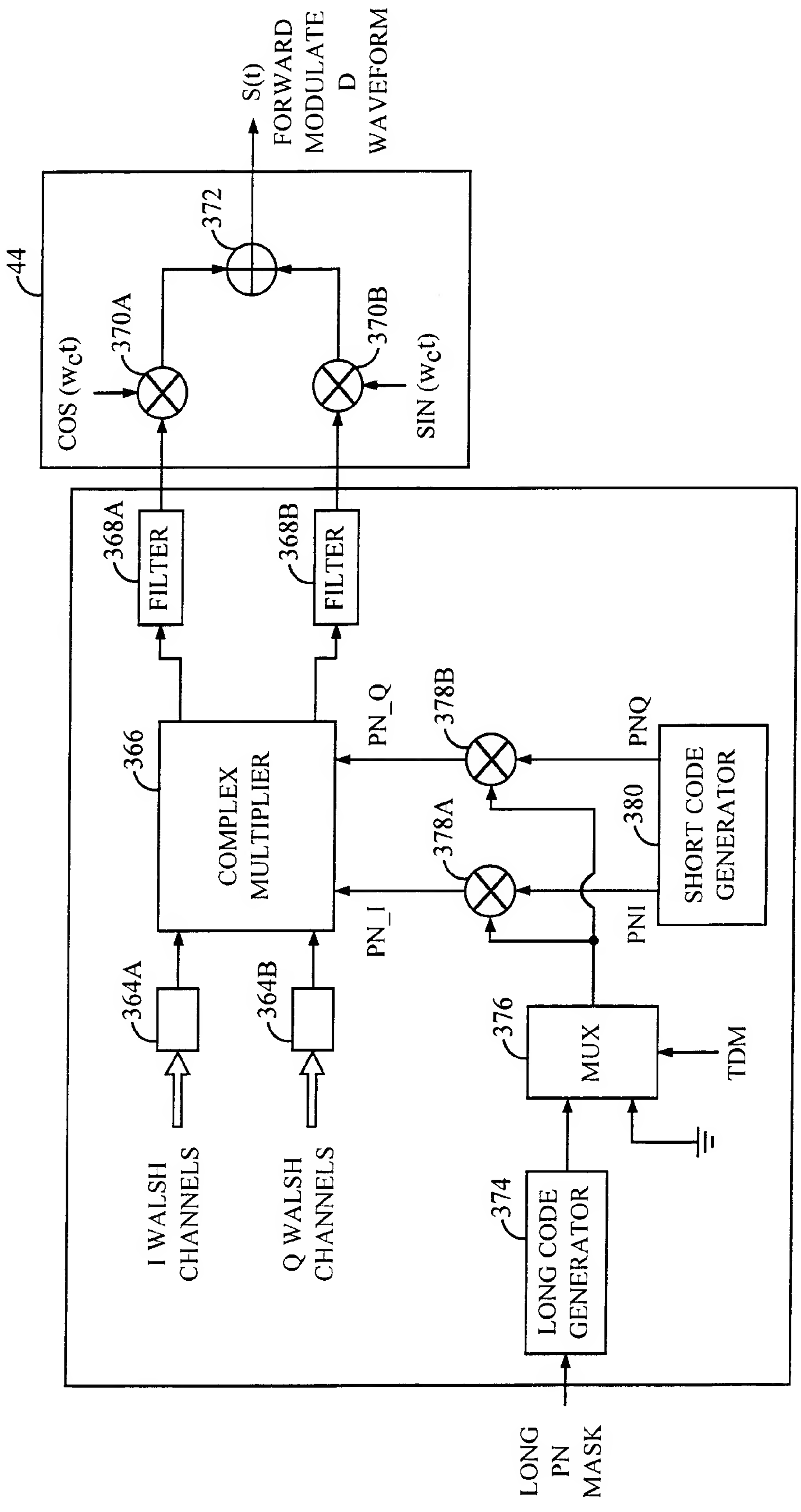

102, 104
DATA INPUT
312
CRC ENCODER
314
ENCODER
DRC
316
INTER-LEAVER
318
FRAME PUNCTURE ELEMENT
320
322
SCRAMBLER
LC STATE
330
VARIABLE RATE CONTROLLER
DRC
1..K I CHANNELS
1..K Q CHANNELS
332
WALSH COVER ELEMENT
DRC
334
GAIN ELEMENT
DRC
336
W1
PREAMBLE
360
MUX
362
MUX
I
Q
I
Q
I
I WALSH CHANNELS
Q WALSH CHANNELS
350
SYMBOL REPEATER
POWER CONTROL CHANNEL DATA
1..M
M+1..N
FAB
BUSY TONE
352
WALSH COVER ELEMENT
354
GAIN ELEMENT
356
PILOT DATA
W0

FIG. 3A



44
COS (wct)
370A
372
S(t)
FORWARD
MODULATE
D
WAVEFORM
370B
SIN (wct)
368A
FILTER
368B
FILTER
366
COMPLEX
MULTIPLIER
PN_Q
378B
PNQ
PN_I
378A
380
SHORT CODE
GENERATOR
PNI
364A
364B
I WALSH
CHANNELS
Q WALSH
CHANNELS
376
MUX
TDM
374
LONG CODE
GENERATOR
LONG
PN
MASK

FIG. 3B

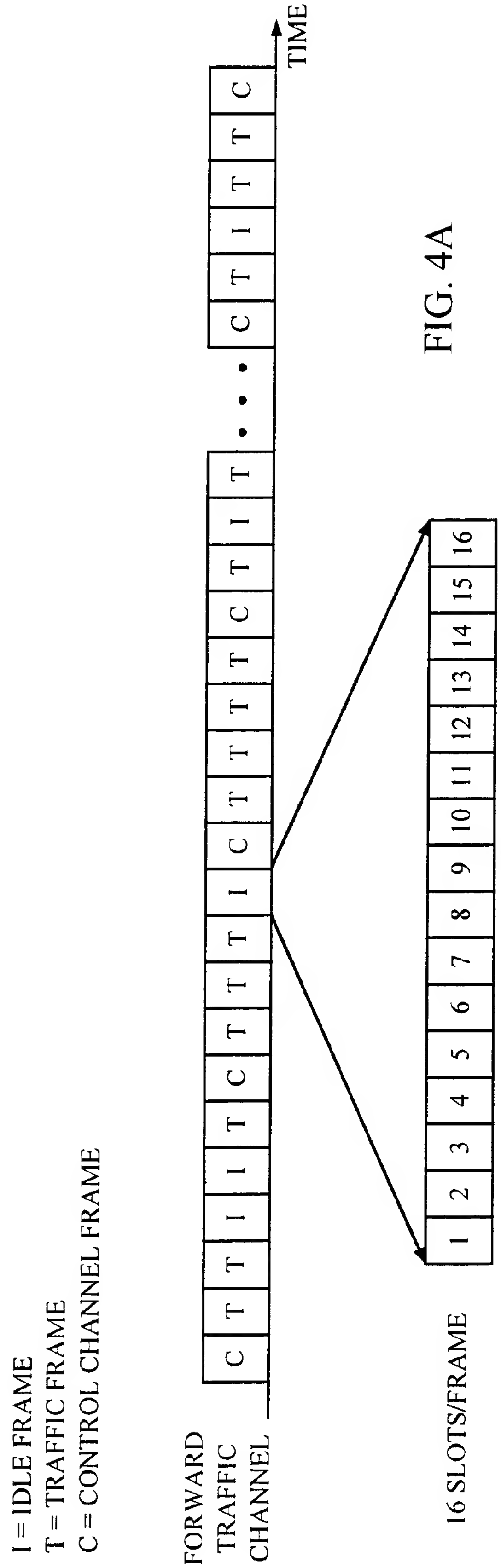

I = IDLE FRAME
T = TRAFFIC FRAME
C = CONTROL CHANNEL FRAME
FORWARD TRAFFIC CHANNEL
C T T I I T C T T T I C T T T T C T I T
C T I T T C
TIME
16 SLOTS/FRAME
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

FIG. 4A

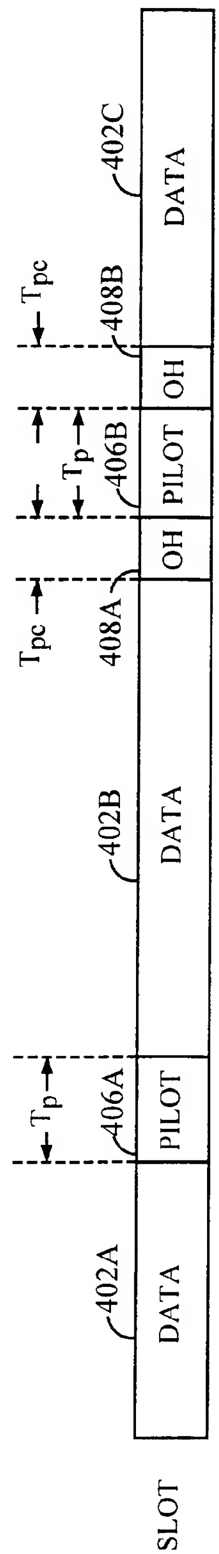

SLOT
DATA
402A
PILOT
406A
T_p
DATA
402B
408A
T_{pc}
OH
PILOT
406B
T_p
OH
408B
T_{pc}
DATA
402C

FIG. 4B

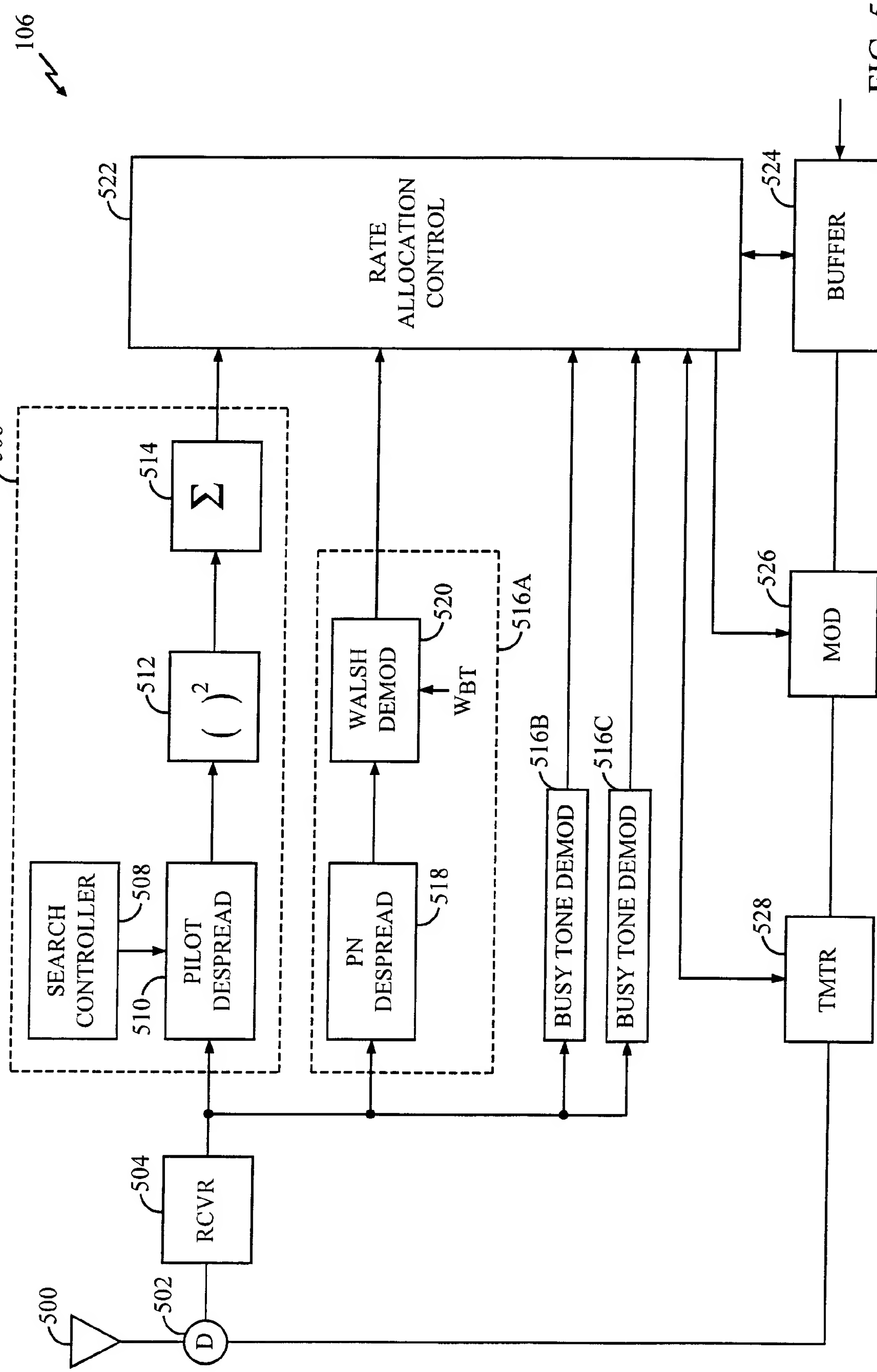

106
500
502
D
504
RCVR
506
SEARCH CONTROLLER
508
510
PILOT DESPREAD
512
( )2
514
Σ
518
PN DESPREAD
520
WALSH DEMOD
WBT
516A
516B
BUSY TONE DEMOD
516C
BUSY TONE DEMOD
522
RATE ALLOCATION CONTROL
524
BUFFER
526
MOD
528
TMTR

FIG. 5

INTERNATIONAL SEARCH REPORT

In. ational Application No
PCT/US 00/26878

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/38 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 09779 A (QUALCOMM INC) 25 February 1999 (1999-02-25) page 14, line 2 - line 12 page 18, line 30 - line 33 page 20, line 23 -page 21, line 11 page 23, line 24 - line 30 page 25, line 10 - line 15 page 30, line 10 -page 32, line 10 page 43, line 17 - line 27 page 44, line 20 - line 37 page 55, line 37 -page 56, line 10 ---	1-59

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 February 2001	08/02/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Heinrich, D

1

In ational Application No
PCT/US 00/26878

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 99 17582 A (ERICSSON TELEFON AB L M) 8 April 1999 (1999-04-08) page 6, line 2 - line 16 page 8, line 3 - line 5 page 8, line 15 - line 31 page 10, line 29 -page 11, line 9 ---	1,2,28, 55,57,58 3-27, 29-54, 56,59
E	WO 01 03357 A (QUALCOMM INC) 11 January 2001 (2001-01-11) page 5, line 13 - line 28 page 6, line 6 - line 27 page 8, line 21 - line 33 -----	1,28,55, 57-59

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

In .ational Application No
PCT/US 00/26878

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 9909779	A	25-02-1999	US	5923650	A	13-07-1999
			AU	9201398	A	08-03-1999
			EP	1005775	A	07-06-2000
WO 9917582	A	08-04-1999	US	6028851	A	22-02-2000
			AU	9287498	A	23-04-1999
			BR	9812836	A	08-08-2000
			CN	1271504	T	25-10-2000
			EP	1018280	A	12-07-2000
WO 0103357	A	11-01-2001	NONE			

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International Bureau

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23 May 2002 (23.05.2002)

PCT

(10) International Publication Number
WO 02/41531 A2

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(74) Agent: **WADSWORTH, Philip, R.**; Baker, Kent D., Qualcomm Incorporated, 5775 Morehouse Drive, San Diego, CA 92121-1714 (US).

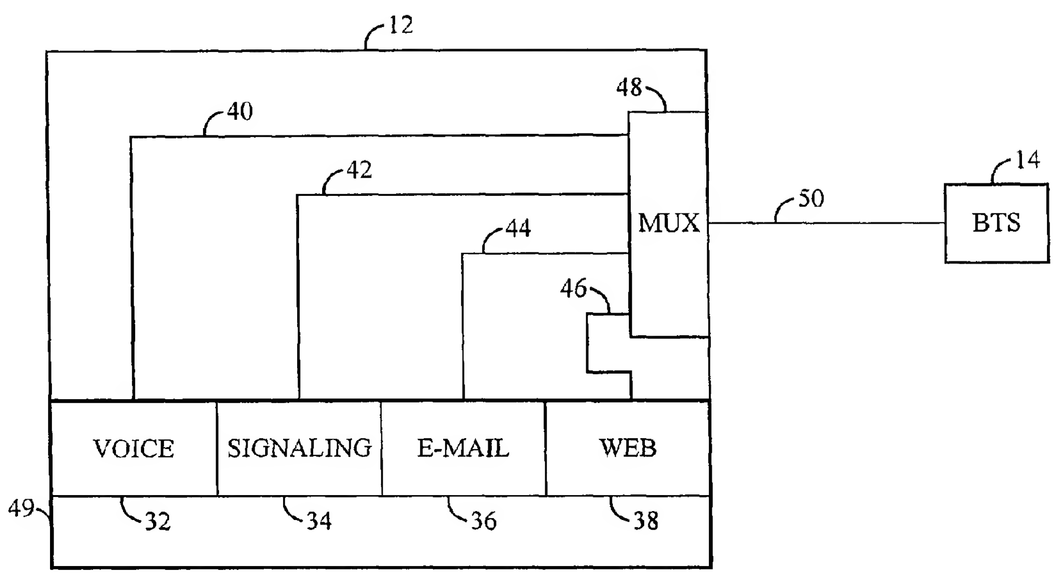
(81) **Designated States** *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR ALLOCATING DATA STREAMS ONTO A SINGLE CHANNEL



(57) Abstract: A method and system that enables multiplexing a plurality of data streams onto one data stream based on data stream priorities and available transport frame combinations (TFCs) is disclosed. A mobile station 12 has applications that produce separate data streams. Example applications include voice 32, signaling 34, E-mail 36 and web applications 38. The data streams are combined by a multiplexer module 48 into one data stream called the transport stream 50. The transport stream 50 is sent over the reverse link to base station transceivers (BTS) 14. The multiplexer module 48 multiplexes the data streams onto the transport stream according to their priorities and the available TFCs.

WO 02/41531 A2

METHOD AND APPARATUS FOR ALLOCATING DATA STREAMS ONTO A SINGLE CHANNEL

BACKGROUND

I. Field

The present invention pertains generally to the field of communications and more specifically to a novel and improved system and method for allocating a plurality of data streams onto a single channel.

II. Background

A remote station is located within a network. The remote station includes applications that produce logical data streams. The remote station allocates the logical data streams onto a single transport stream. A technique for multiplexing data from logical data streams onto a transport stream is disclosed in U.S. Application Serial No. 09/612,825, filed February 8, 1999, entitled "METHOD AND APPARATUS FOR PROPORTIONATELY MULTIPLEXING DATA STREAMS ONTO ONE DATA STREAM," which is assigned to the assignee of the present invention and incorporated by reference herein.

Choosing an allocation scheme for allocating bits from multiple data streams onto a single channel is difficult because a number of factors have to be taken into consideration. One factor that has to be considered is the priority of each data stream. Higher priority data streams take precedence over lower priority data streams. Another factor that has to be considered is the type of transport format combinations (TFCs) that are allowed. A TFC is a combination of transport frames to be sent out on a wireless link of the remote station at each time slot. A transport format has a number of blocks (i.e. one or more blocks) and a block size. An allocation scheme that takes

into consideration the priority of data streams and the TFCs available is desired.

It is also desirable to have an allocation scheme that selects TFCs without having to pad the TFCs, which wastes valuable space. In addition, throughput is improved when TFC do not have to be padded because the TFCs that are transmitted over the transport channel are full. Some allocation schemes pad TFCs. In these padded allocation schemes, a TFC is padded when the TFC is not completely filled with bits from the logical data streams.

SUMMARY

The presently disclosed method and apparatus are directed to allocating a plurality of data streams onto one data stream for transmission. A list of allowable TFCs is received from a network. Bits from data streams at a logical level are placed into TFCs at a transport level based on the priority of the data streams and the TFCs available.

In one aspect, a plurality of applications provides a plurality of data streams to be allocated to a single stream. In another aspect, subcriber units provide a plurality of data streams to be allocated to a single stream of a base station. In still another embodiment, a plurality of base stations provides a plurality of data streams to be multiplexed by a multiplexer within a base station controller. Multiplexer could be a processor or a processor capable of traditional multiplexing tasks such as combining multiple input streams of data into one output or separating into multiple output streams of data from a single input stream of data. Multiplexer could also be a processor capable of logical decisions or a processor capable of other operation functions.

In one aspect, a subscriber unit comprises a memory, a plurality of applications residing in the memory, each application producing a data stream wherein each data stream comprises at least one bit, and a

multiplexer configured to receive each data stream and uniformly distribute bits from the plurality of data streams onto a single data stream.

In one aspect, the multiplexer is configured to receive each data stream and uniformly distribute bits from the plurality of data streams onto a single data stream based on the proportion value.

In another aspect, a multiplexer is configured to receive each of a plurality of data streams and uniformly distribute bits from the plurality of data streams onto a single data stream based primarily on the data streams' proportion value and secondarily on the data streams' priority.

In still another aspect, a wireless communication system comprises a subscriber unit, a base station coupled to the subscriber unit, and a base station controller coupled to the base station. The subscriber unit includes a plurality of applications and a multiplexer, wherein each application produces a data stream as input to the multiplexer and each data stream comprises at least one bit. The multiplexer distributes bits from the data streams onto a single stream based on allowable TFCs not requiring padding.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a schematic overview of an exemplary cellular telephone system;

FIG. 2 shows a block diagram of a mobile station and a base station in accordance with an embodiment;

FIGS. 3A-3B show a flowchart for the elimination of TFCs based on availabe bits in an embodiment; and

FIGS. 4A-4C show a flowchart for selecting a TFC in an exemplary embodiment.

DETAILED DESCRIPTION

An exemplary cellular mobile telephone system in which the present invention is embodied is illustrated in FIG. 1. For purposes of example the exemplary embodiment is described herein within the context of a W-CDMA cellular communications system. However, it should be understood that the invention is applicable to other types of communication systems, such as personal communication systems (PCS), wireless local loop, private branch exchange (PBX), or other known systems. Furthermore, systems utilizing other well known multiple access schemes such as TDMA and FDMA as well as other spread spectrum systems may employ the presently disclosed method and apparatus.

As illustrated in FIG. 1, a wireless communication network **10** generally includes a plurality of mobile stations (also called mobiles, subscriber units, remote station, or user equipment) **12a-12d**, a plurality of base stations (also called base station transceivers (BTSs) or Node B), **14a-14c**, a base station controller (BSC) (also called radio network controller or packet control function **16**), a mobile station controller (MSC) or switch **18**, a packet data serving node (PDSN) or internetworking function (IWF) **20**, a public switched telephone network (PSTN) **22** (typically a telephone company), and an Internet Protocol (IP) network **24** (typically the Internet). For purposes of simplicity, four mobile stations **12a-12d**, three base stations **14a-14c**, one BSC **16**, one MSC **18**, and one PDSN **20** are shown. It would be understood by those skilled in the art that there could be any number of mobile stations **12**, base stations **14**, BSCs **16**, MSCs **18**, and PDSNs **20**.

In one embodiment the wireless communication network **10** is a packet data services network. The mobile stations **12a-12d** may be any of a number of different types of wireless communication device such as a portable phone, a cellular telephone that is connected to a laptop computer running IP-based, Web-browser applications, a cellular telephone with an

associated hands-free car kit, a personal digital assistant (PDA) running IP-based, Web-browser applications, a wireless communication module incorporated into a portable computer, or a fixed location communication module such as might be found in a wireless local loop or meter reading system. In the most general embodiment, mobile stations may be any type of communication unit.

The mobile stations **12a-12d** may advantageously be configured to perform one or more wireless packet data protocols such as described in, for example, the EIA/TIA/IS-707 standard. In a particular embodiment, the mobile stations **12a-12d** generate IP packets destined for the IP network **24** and encapsulate the IP packets into frames using a point-to-point protocol (PPP).

In one embodiment the IP network **24** is coupled to the PDSN **20**, the PDSN **20** is coupled to the MSC **18**, the MSC **18** is coupled to the BSC **16** and the PSTN **22**, and the BSC **16** is coupled to the base stations **14a-14c** via wirelines configured for transmission of voice and/or data packets in accordance with any of several known protocols including, e.g., E1, T1, Asynchronous Transfer Mode (ATM), IP, PPP, Frame Relay, HDSL, ADSL, or xDSL. In an alternate embodiment, the BSC **16** is coupled directly to the PDSN **20**, and the MSC **18** is not coupled to the PDSN **20**. In one embodiment, the mobile stations **12a-12d** communicate with the base stations **14a-14c** over an RF interface defined in the <u>3rd Generation Partnership Project 2 "3GPP2"</u>, "Physical Layer Standard for cdma2000 Spread Spectrum Systems," 3GPP2 Document No. C.P0002-A, TIA PN-4694, to be published as TIA/EIA/IS-2000-2-A, (Draft, edit version 30) (Nov. 19, 1999) (hereinafter "cdma 2000"), which is fully incorporated herein by reference.

During typical operation of the wireless communication network **10**, the base stations **14a-14c** receive and demodulate sets of reverse-link signals from various mobile stations **12a-12d** engaged in telephone calls, Web browsing, or other data communications. Each reverse-link signal received

by a given base station **14a-14c** is processed within that base station **14a-14c.** Each base station **14a-14c** may communicate with a plurality of mobile stations **12a-12d** by modulating and transmitting sets of forward-link signals to the mobile stations **12a-12d**. For example, as shown in FIG. 1, the base station **14a** communicates with first and second mobile stations **12a, 12b** simultaneously, and the base station **14c** communicates with third and fourth mobile stations **12c, 12d** simultaneously. The resulting packets are forwarded to the BSC **16**, which provides call resource allocation and mobility management functionality including the orchestration of soft handoffs of a call for a particular mobile station **12a-12d** from one base station **14a-14c** to another base station **14a-14c**. For example, a mobile station **12c** is communicating with two base stations **14b, 14c** simultaneously. Eventually, when the mobile station **12c** moves far enough away from one of the base stations **14c**, the call will be handed off to the other base station **14b**.

If the transmission is a conventional telephone call, the BSC **16** will route the received data to the MSC **18**, which provides additional routing services for interface with the PSTN **22**. If the transmission is a packet-based transmission such as a data call destined for the IP network **24**, the MSC **18** will route the data packets to the PDSN **20**, which will send the packets to the IP network **24**. Alternatively, the BSC **16** will route the packets directly to the PDSN **20**, which sends the packets to the IP network **24**.

The wireless communication channel through which information signals travel from a mobile station **12** to a base station **14** is known as a reverse link. The wireless communication channel through which information signals travel from a base station **14** to a mobile station **12** is known as a forward link.

CDMA systems are typically designed to conform to one or more standards. Such standards include the "TIA/EIA/IS-95-B Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" (the IS-95 standard), the "TIA/EIA/IS-98

Recommended Minimum Standard for Dual-Mode Wideband Spread Spectrum Cellular Mobile Station" (the IS-98 standard), the standard offered by a consortium named "3rd Generation Partnership Project" (3GPP) and embodied in a set of documents including Document Nos. 3G TS 25.211, 3G TS 25.212, 3G TS 25.213, 3G TS 25.311 and 3G TS 25.214 (the W-CDMA standard), the "TR-45.5 Physical Layer Standard for cdma2000 Spread Spectrum Systems" (the cdma2000 standard), and the "TIA/EIA/IS-856 cdma2000 High Rate Packet Data Air Interface Specification" (the HDR standard). New CDMA standards are continually proposed and adopted for use. These CDMA standards are incorporated herein by reference.

More information concerning a code division multiple access communication system is disclosed in U.S. Patent No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS," and US. Pat. No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING WAVEFORMS IN A CDMA CELLULAR TELPHONE SYSTEM," both of which are assigned to the assignee of the present invention, and are incorporated in their entirety by reference herein.

CDMA 2000 is compatible with IS-95 systems in many ways. For example, in both the cdma2000 and IS-95 systems, each base station time-synchronizes its operation with other base stations in the system. Typically, the base stations synchronize operation to a universal time reference such as Global Positioning System (GPS) signaling; however, other mechanisms can be used. Based upon the synchronizing time reference, each base station in a given geographical area is assigned a sequence offset of a common pseudo noise (PN) pilot sequence. For example, according to IS-95, a PN sequence having 2^{15} chips and repeating every 26.67 milliseconds (ms) is transmitted as a pilot signal by each base station. The pilot PN sequence is transmitted by each base station at one of 512 possible PN sequence offsets. Each base station transmits the pilot signal continually, which enables mobile stations to identify the base station's transmissions as well as for other functions.

In an exemplary embodiment, a mobile station communicates with a base station using wideband code division multiple access (W-CDMA) techniques. The base stations in a W-CDMA system operate asynchronously. That is, the W-CDMA base stations do not all share a common universal time reference. Different base stations are not time-aligned. Thus, although a W-CDMA base station has a pilot signal, a W-CDMA base station may not be identified by its pilot signal offset alone. Once the system time of one base station is determined, it cannot be used to estimate the system time of a neighboring base station. For this reason, a mobile station in a W-CDMA system use a three-step PERCH acquisition procedure to synchronize with each base station in the system. Each step in the acquisition procedure identifies a different code within a frame structure called a PERCH channel.

In an exemplary embodiment, a mobile station has a plurality of applications. The applications reside within the mobile station and each application produces a separate data stream. An application may produce more than one data stream.

FIG. 2 shows a block diagram of a mobile station **12** and a base station **14** in accordance with an exemplary embodiment. The mobile station **12** includes voice **32**, signaling **34**, E-mail **36** and web applications **38** residing in the memory **49** of the mobile station **12**. Each application, voice **32**, signaling **34**, E-mail **36** and web application **38** produces a separate data stream **40, 42, 44, 46**, respectively. The data streams are multiplexed by a multiplexer module **48** into one data stream called the transport stream **50**. The transport stream **50** is sent over the reverse link to a base transceiver station **14** (BTS), also called a base station for short.

Each data stream **40-46** has a priority. The multiplexer module **48** places bits from data streams at a logical level into TFCs at the transport level based on the priority of the data streams and the TFCs available without having to pad the TFCs. Other systems pad TFCs that are not filled

with bits from the data streams. However, embodiments of the present invention do not pad the TFCs.

In an exemplary embodiment, the multiplexer module **48** operates within the media-access control (MAC) layer and gets the data stream priorities from a higher network layer. The MAC layer defines the procedures used to receive and transmit over the physical layer.

As would be apparent to one of ordinary skill in the art, the data streams **40-46** can be prioritized with any priority scheme known in the art, such as first-in-first-out (FIFO), last-in-first-out (LIFO), and shortest-job-first (SJF). As would be apparent to one of ordinary skill in the art, the multiplexer module **48** can operate on a plurality of network levels.

In another embodiment, the multiplexer module **48** is executed in hardware. In yet another embodiment, the multiplexer module **48** is executed in a combination of software and hardware. As would be apparent to one of ordinary skill in the art, the multiplexer module **48** can be executed by any combination of software and hardware.

In an embodiment, the multiplexer module **48** employs an allocation algorithm. For any given time slot, the allocation algorithm eliminates TFCs that need to be padded. Thus, only TFCs that do not need padding are valid. For a given time slot, TFCs needing padding are invalid.

If the allocation algorithm did not eliminate invalid TFCs, the allocation algorithm could select a TFC requiring padding. Selecting a TFC that allows the transmission of the most high priority bits may result in an invalid TFC being selected. The TFC could be invalid because the TFC selected results in high priority bits being transmitted, but there are bits available within the TFC for other lower priority logical channels. In order to avoid an invalid TFC being selected, it is necessary for the allocation algorithm of an embodiment to eliminate invalid TFCs before selecting a TFC.

A set of allowable TFCs is received from the network. The set is called the transport frame combination set (TFCS). The TFCs in the TFCS

are allowable in the sense that the network allows the TFCs to be transported through the network.

In one embodiment, the allocation algorithm has at least three steps as shown below:

(1) Set S1 to the set of TFCs in the TFCS that can be used based on the current maximum transmitter power;

(2) Set S2 to the set of TFCs in S1 that can be used based on the current bit availability from the different logical channels given that introducing "padding" blocks is not allowed; and

(3) Pick the TFC from S2 that allows the transmission of the most high priority bits.

In another embodiment, steps (1) and (2) are reversed. Another embodiment includes steps (2) and (3), but not step (1). Each one of the steps is described in more detail below.

In step (1), TFCs are eliminated from the set of allowable TFCs based on power requirements. Each TFC requires a certain amount of power in order to be transmitted. The power requirement for each TFC is computed. The TFCs that require more power than can be currently transmitted are eliminated. The TFCs that do not require more power than can be currently transmitted remain.

The second step is the elimination of remaining TFCs that require padding blocks based on available bits. The TFCs having available bits are eliminated. Each TFC is checked for empty blocks.

BS_{ij} is the block size and BSS_{ij} is the block set size in the ith TFC (of the allowable TFCs) for the jth transport channel. Let B_{ik} be the buffer occupancy for the kth logical channel corresponding to the ith transport channel. It is assumed that the block size and block set size are adjusted for the MAC header and that therefore there is a strict correspondence with the buffer

occupancy. A TFC is acceptable only if it cannot contain more bits than are available for any of the transport channels. The remaining pseudo-code for the elimination of TFCs based on available bits is shown below:

1. Set S2 = S1.
2. Let there be n transport channels numbered from 1 through n.
3. Set i = 1. This will be the index for all transport channels.
4. Let Sb be the set of block sizes that exist in any TFC in S2 for the i^{th} transport channel.
5. Pick a block size BS from Sb.
6. Let St be the set of m TFCs in S2, numbered 1 through m, that have block size BS for the i^{th} transport channel.
7. Set j = 1. This will be the index for the TFCs in St.
8. Compute: $T = BS \cdot \sum_k \left\lceil \frac{B_{ik}}{BS} \right\rceil$.
9. If $BSS_{ji} \leq T$ then go to 11. Where BSS_{ji} corresponds to the i^{th} trasport channel for the j^{th} TFC in St.
10. S2 = S2 – {TFCj}. Where TFCj is the j^{th} TFC in St.
11. j += 1.
12. If j ≤ m then go to step 9.
13. Set Sb = Sb –{BS}.
14. If Sb ≠ {∅} then go to step 5.
15. Set i += 1.
16. If i ≤ n then go to step 4.
17. The algorithm is complete and the valid TFCs are in S2.

FIGS. 3A-3B show a flowchart in one embodiment for the elimination of TFCs based on available bits. Set S2 is set to S1 **100**. S1 is the set of allowable TFCs that do not require more power than can be transmitted. Let there be n transport channels numbered from 1 through n **102**. Initialize index i **104**. Index i is the index for the transport channels. Let Sb be the set of all block sizes that exist in any TFC in set S2 for the i^{th} transport channel **106**. Select block size BS from set Sb **108**. Let St be the set of m TFCs in set S2, numbered 1 through m, that have block size BS for the

i^{th} transport channel **110**. Initialize index j **112**. Index j is the index for the TFCs in set St. Compute a threshold $T = BS \cdot \sum_k \left\lceil \frac{B_{ik}}{BS} \right\rceil$ **114**. Threshold T is used to check whether there is too much space in a TFC. If the Block Set Size$BSS_{ji} \leq T$ **116**, then index j is incremented **118**, otherwise there is too much space such that the TFC would require padding blocks and the TFC_j is removed from set S2 **120** and index j is incremented **118**. If there are more TFCs to process, i.e., $j \leq m$ then go back and check if the Block Set Size$BSS_{ji} \leq T$ **116**, otherwise substract the entry with this block size from set Sb by the block size **124**. If Sb is non-null **126**, then go back and select another block size BS **108**, otherwise increment index i **128**. If all the transport channels have not been processed, i.e., $i \leq n$ **130**, then Let Sb be the set of all block sizes that exist in any TFC in set S2 for the next transport channel **106**. If i>n, then all invalid TFCs have been removed from set of available TFC that do not require more power than can be transmitted. The valid TFCs are in set S2.

In one embodiment, all of the TFCs with the same block size (on the ith transport channel) are grouped in S2. In another embodiment, TFCs with the same block size do not have to be grouped together. In this embodiment, T is computed every time a different TFC is examined.

The third step is the selection of the optimum TFC. Bits from the logical data streams are hypothetically loaded into the TFC. The loaded TFCs are compared based on the amount of high priority data they contain.

There are n priority levels, P_1 through P_n with P_1 being the highest priority. Let there be q TFCs in S2, numbered from 1 to q. For each TFC in S2, create a variable NOB (number of bits) and for each one of the transport channels on each TFC, create a variable SAS (still available space). All SAS shall be initialized to the corresponding TFC block set size. NOB_i and SAS_{ij} are the variables for the ith TFC in S2 and the jth transport channel. L_{ij} is

the jth logical channel at priority level P_i. Then the following algorithm can be performed:

1. Set S3 = S2.
2. Set i = 1. This is going to be the index for the priority levels.
3. Initialize the NOBs for all TFCs in S3 to 0.
4. Let m be the number of logical channels of priority Pi.
5. Set j = 1. This is going to be the index for the logical channels at the current priority level.
6. Let Bij be the number of available bits for logical channel Lij.
7. Let l be the transport channel on which logical channel j is mapped.
8. Set k = 1. This will be the index of TFCs in S3.
9. If $\left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS < SAS_{kl}$ then go to step 13.
10. $NOB_k += SAS_{kl}$.
11. $SAS_{kl} = 0$.
12. Go to step 15.
13. $NOB_k += \left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS$. (It is also possible to do: $NOB_k += B_{ij}$. But this makes the outcome order dependent.).
14. $SAS_{kl} -= \left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS$.
15. k += 1.
16. If k ≤ q then go to step 9.
17. j += 1 ; Logical Channels
18. If j ≤ m then go to step 6.
19. Keep in S3 the TFCs for which the NOB is the highest.
20. If there is no TFC in S3, then go to the next time slot.
21. If there is a single TFC in S3 then the algorithm is complete. The single TFC is used. Go to the next time slot.
22. i += 1. ; Priority
23. If i ≤ n then go to step 3.
24. Pick arbitrarily one of the TFCs in S3. Go to the next time slot.

FIGS. 4A-4C show a flowchart for selecting a TFC in an exemplary embodiment. Set S3 is set to set S2 **140**, which is the set of valid TFCs. Set S3 shall provide a set of TFCs that can be selected for transport. The index for the priority levels, index i is initialized **142**. There is an NOB variable for all TFCs in set S3. NOB stands for number of bits. The NOB variables for all TFCs in S3 are initialized to zero **144**. Let m be the number of logical channels of priority P_I **146**. The index for the logical channels at the current priority level, index j, is initialized to one **148**. Let Bij be the number of available bits for logical channel Lij **150**. Logical channels are mapped to transport channels. l is the transport channel on which logical channel j is mapped **152**. Initialize the index of the TFCs in set S3, k, to one.

If there is still available space after filling Bij, i.e., $\left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS < SAS_{kl}$ 156, then increment NOBk by $\left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS_{kl}$ 158 and substract $\left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS_{kl}$ from SASkl 160. Then, increment index k 166. If there is no available space after filling Bij, then increment the number of bits NOBk by SASkl 162 and reset SASkl to zero 164. Increment index k 166. If the TFCs in S2 have not been processed for this logical channel, i.e, if k ≤ q 168, then go back to fill more TFCs, i.e., $\left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS < SAS_{kl}$ **156**. If the TFCs in S2 have been processed for this logical channel, then increment index j **170**. If index j ≤ m then go back and let Bij be the number of available bits for logical channel Lij **150**. Otherwise put the TFCs for which the NOB is the highest in set S3 **174**. If there is a single TFC in S3 **180**, then the single TFC is used **182**. Go to the next time slot **178**. If there is more than one TFC in S3, then increment index i **184**. If i ≤ n **186**, then go back and initialize the NOB variables for all TFCs in S3 to zero **144** and continue the algorithm. Otherwise, all transport channels have been processed. One of the TFCs in S3 can be arbitrarily chosen for transmission **188**. Go to the next time slot **178**.

As would be apparent to one of ordinary skill in the art, the TFC algorithm can be applied to other interconnections between network modules. It can be applied to any situation where a module has a plurality of inputs and produces a multiplexed output from the plurality of inputs. For example, a multiplexer module can be located within a BTS wherein the BTS multiplexes data streams from a plurality of mobile stations and produces a multiplexed data stream to be sent to the BSC.

Thus, a novel and improved method and apparatus for multiplexing multiple data streams onto one data stream have been described. Those of skill in the art would understand that the various illustrative logical blocks, modules, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. The various illustrative components, blocks, modules, circuits, and steps have been described generally in terms of their functionality. Whether the functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans recognize the interchangeability of hardware and software under these circumstances, and how best to implement the described functionality for each particular application. As examples, the various illustrative logical blocks, modules, and algorithm steps described in connection with the embodiments disclosed herein may be implemented or performed with a processor executing a set of firmware instructions, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components such as, e.g., registers, any conventional programmable software module and a processor, or any combination thereof designed to perform the functions described herein. The multiplexer may advantageously be a microprocessor, but in the alternative, the multiplexer may be any conventional processor, controller, microcontroller, or state machine. The applications could reside in RAM

memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. As illustrated in FIG. 2, a base station **14** is advantageously coupled to a mobile station **12** so as to read information from the base station **14.** The memory **49** may be integral to the multiplexer **48**. The multiplexer **48** and memory **49** may reside in an ASIC (not shown). The ASIC may reside in a telephone **12**.

The previous description of the embodiments of the invention is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WE CLAIM:

CLAIMS

1. A method for multiplexing a plurality of data streams onto one data stream, comprising:

receiving a set of transport frame combinations from a network; and

selecting a transport frame combination (TFC) from the received set based on whether at least one TFC in the received set can be filled with bits from a plurality of data streams.

2. The method of claim 1, further comprising filling the selected TFC with bits from the plurality of data streams.

3. The method of claim 2, further comprising scheduling the selected TFC for transport.

4. The method of claim 2, further comprising allocating the TFC to a single transport stream.

5. The method of claim 2, wherein the selecting a TFC is also based on the priority of the plurality of data streams.

6. The method of claim 2, further comprising comparing the selected TFC with other TFCs from the set of TFCs.

7. The method of claim 6, wherein the selected TFC includes more bits from the highest priority data stream than other TFCs in the set of TFCs.

8. The method of claim 6, wherein the selected TFC includes more high priority bits from the plurality of data streams as compared to other TFCs in the set of TFCs.

9. A subscriber unit, comprising:
a memory;
a plurality of applications residing in the memory, each application capable of producing a data stream, wherein each data stream comprises at least one bit; and
a multiplexer configured to receive each data stream, receive a set of TFCs, and select a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from a plurality of data streams.

10. The subscriber unit of claim 9, wherein the multiplexer is configured to fill the selected TFC with bits from the plurality of data streams.

11. The subscriber unit of claim 10, wherein the multiplexer is configured to schedule the selected TFC for transport.

12. The subscriber unit of claim 10, wherein the multiplexer is configured to allocate the TFC to a single transport stream.

13. The subscriber unit of claim 10, wherein the multiplexer is configured to select the TFC based on the priority of data streams.

14. The subscriber unit of claim 10, wherein the multiplexer is configured to compare the selected TFC with other TFCs from the set of TFCs.

15. The subscriber unit of claim 14, wherien the multiplexer is configured to select the TFC that includes more bits from the highest priority data stream of the plurality of data streams than other TFC in the set of TFCs.

16. The subscriber unit of claim 14, wherein the multiplexer is configured to select the TFC that includes more high priority bits from the plurality of data streams as compared to other TFCs in the set of TFCs.

17. A base station, comprising:

a memory;

a plurality of applications residing in the memory, each application capable of producing a data stream, wherein each data stream comprises at least one bit; and

a multiplexer configured to receive each data stream, receive a set of TFCs, and select a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from a plurality of data streams.

18. The base station of claim 17, wherein the multiplexer is configured to fill the selected TFC with bits from the plurality of data streams based on the priorities of the plurality of data streams.

19. A base station controller, comprising:

a memory;

a plurality of applications residing in the memory, each application capable of producing a data stream, wherein each data stream comprises at least one bit; and

a multiplexer configured to receive each data stream, receive a set of TFCs, and select a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from a plurality of data streams.

20. The base station controller of claim 19, wherein the multiplexer is configured to fill the selected TFC with bits from the plurality of data streams based on the priorities of the plurality of data streams.

21. An apparatus for combining data from a plurality of data sources for transmission as a single data stream, the apparatus comprising;

a memory; and

a multiplexer, communicatively attached to said memory, said multiplexer for:

receiving plural data streams from said data sources, each data stream comprising data blocks, containing a number of data bits, data blocks referred to as transport frames;

multiplexing data from said plural data sources onto a single data stream in the form of multiple transport frames configured as transport frame combinations;

receiving a set of transport frame combinations (TFCs); and ,

selecting a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from said plurality of data streams.

22. The apparatus of claim 21, wherein the multiplexer is also for filling the selected TFC with bits from the plurality of data streams

23. The apparatus of claim 22, wherein the multiplexer is also for scheduling the selected TFC for transport.

24. The apparatus of claim 22, wherein the multiplexer is also for allocating the TFC to a single transport stream.

25. The apparatus of claim 22, wherein the multiplexer is for selecting a TFC also based on the priority of the plurality of data streams.

26. The apparatus of claim 22, wherein the multiplexer is also for comparing the selected TFC with the other TFC's from the set of received TFCs.

27. The apparatus of claim 26, wherein the multiplexer is for selecting a TFC also based on whether the selected TFC has more bits from the highest priority data stream than other TFCs in the set of received TFCs.

28. The apparatus of claim 26, wherein the multiplexer is for selecting a TFC also based on whether the selected TFC includes more high priority bits from the plurality of data streams as compared to the other TFCs in the set of received TFCs.

29. A method for combining data from a plurality of data sources for transmission as a single data stream, the method comprising;

receiving plural data streams from said data sources, each data stream comprising

data blocks, containing a number of data bits, data blocks referred to as transport frames;

multiplexing data from said plural data sources onto a single data stream in the

form of multiple transport frames configured as transport frame combinations;

receiving a set of transport frame combinations (TFCs) ; and ,

selecting a TFC from the received set based on whether at least one TFC in the

received set can be filled with bits from said plurality of data streams.

30. The method of claim 29, further comprising filling the selected TFC with bits from the plurality of data streams.

31. The method of claim 30, further comprising scheduling the selected TFC for transport.

32. The method of claim 30, further comprising allocating the TFC to a single transport stream.

33. The method of claim 30, wherein the selecting of a TFC is also based on the priority of the plurality of data streams.

34. The method of claim 30, further comprising comparing the selected TFC with the other TFC's from the set of received TFCs.

35. The method of claim 34, wherein the selecting of a TFC is also based on whether the TFC includes more bits from the highest priority data stream than other TFCs in the set of received TFCs.

36. The method of claim 34, wherein the selecting of a TFC is also based on whether the TFC includes more high priority bits from the plurality of data streams as compared to the other TFCs in the set of received TFCs.

37. A subscriber unit for combining data from a plurality of data sources for transmission as a single data stream comprising:

a memory; and

a multiplexer , communicatively attached to said memory, said multiplexer for:

receiving plural data streams from said data sources, each data stream comprising data blocks, containing a number of data bits, data blocks referred to as transport frames;

multiplexing data from said plural data sources onto a single data stream in the form of multiple transport frames configured as transport frame combinations;

receiving a set of transport frame combinations (TFCs); and ,

selecting a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from said plurality of data streams

38. The subscriber unit of claim 37, wherein the multiplexer is also for filling the selected TFC with bits from the plurality of data streams

39. The subscriber unit of claim 38, wherein the multiplexer is also for scheduling the selected TFC for transport.

40. The subscriber unit of claim 38, wherein the multiplexer is also for allocating the TFC to a single transport stream.

41. The subscriber unit of claim 38, wherein the multiplexer is for selecting a TFC also based on the priority of the plurality of data streams.

42. The subscriber unit of claim 38, wherein the multiplexer is also for comparing the selected TFC with the other TFC's from the set of received TFCs.

43. The subscriber unit of claim 42, wherein the multiplexer is for selecting a TFC also based on whether the selected TFC has more bits from the highest priority data stream than other TFCs in the set of received TFCs.

44. The subscriber unit of claim 42, wherein the multiplexer is for selecting a TFC also based on whether the selected TFC includes more high priority bits from the plurality of data streams as compared to the other TFCs in the set of received TFCs.

45. A base station for combining data from a plurality of data sources for transmission as a single data stream comprising:

a memory; and

a multiplexer , communicatively attached to said memory, said multiplexer for:

receiving plural data streams from said data sources, each data stream comprising data blocks, containing a number of data bits, data blocks referred to as transport frames;

multiplexing data from said plural data sources onto a single data stream in the form of multiple transport frames configured as transport frame combinations;

receiving a set of transport frame combinations (TFCs); and ,

selecting a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from said plurality of data streams.

46. The base station of claim 45, wherein the multiplexer is also for filling the selected TFC with bits from the plurality of data streams

47. The base station of claim 46, wherein the multiplexer is also for scheduling the selected TFC for transport.

48. The base station of claim 46, wherein the multiplexer is also for allocating the TFC to a single transport stream.

49. The base station of claim 46, wherein the multiplexer is for selecting a TFC also based on the priority of the plurality of data streams.

50. The base station of claim 46, wherein the multiplexer is also for comparing the selected TFC with the other TFC's from the set of received TFCs.

51. The base station of claim 50, wherein the multiplexer is for selecting a TFC also based on whether the selected TFC has more bits from the highest priority data stream than other TFCs in the set of received TFCs.

52. The base station of claim 50, wherein the multiplexer is for selecting a TFC also based on whether the selected TFC includes more high priority bits from the plurality of data streams as compared to the other TFCs in the set of received TFCs.

53. A subscriber unit for combining data from a plurality of data sources for transmission as a single data stream comprising:

means for receiving plural data streams from said data sources, each data stream comprising data blocks, containing a number of data bits, data blocks referred to as transport frames;

means for multiplexing data from said plural data sources onto a single data stream in the form of multiple transport frames configured as transport frame combinations;

means for receiving a set of transport frame combinations (TFCs); and,

means for selecting a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from said plurality of data streams.

54. A base station for combining data from a plurality of data sources for transmission as a single data stream comprising:

means for receiving plural data streams from said data sources, each data stream comprising data blocks, containing a number of data bits, data blocks referred to as transport frames; and

means for multiplexing data from said plural data sources onto a single data stream in the form of multiple transport frames configured as transport frame combinations;

means for receiving a set of transport frame combinations (TFCs); and,

means for selecting a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from said plurality of data streams.

55. A system for communicating data comprising:

a number of subscriber units comprising;

a memory; and

a multiplexer , communicatively attached to said memory, said multiplexer for:

receiving plural data streams from said data sources, each data stream comprising data blocks, containing a number of data bits, data blocks referred to as transport frames;

multiplexing data from said plural data sources onto a single data stream in the form of multiple transport frames configured as transport frame combinations;

receiving a set of transport frame combinations (TFCs); and,

selecting a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from said plurality of data streams;

and,

a number of base stations comprising;

a memory; and

a multiplexer , communicatively attached to said memory, said multiplexer for:

receiving plural data streams from said data sources, each data stream comprising data blocks, containing a number of data bits, data blocks referred to as transport frames;

multiplexing data from said plural data sources onto a single data stream in the form of multiple transport frames configured as transport frame combinations;

receiving a set of transport frame combinations (TFCs); and

selecting a TFC from the received set based on whether at least one TFC in the received set can be filled with bits from said plurality of data streams.

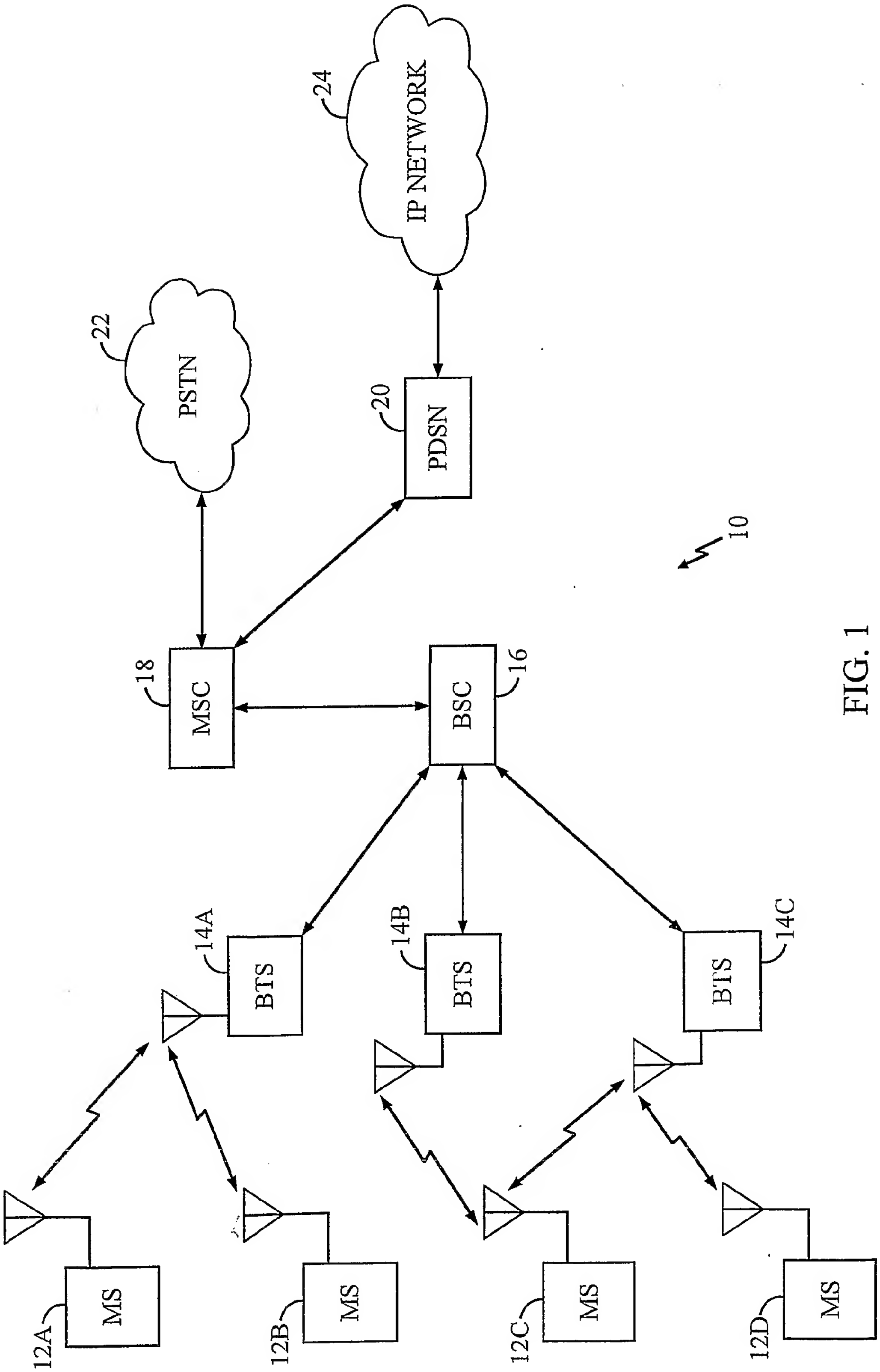

IP NETWORK
24
PSTN
22
PDSN
20
MSC
18
BSC
16
10
BTS
14A
BTS
14B
BTS
14C
MS
12A
MS
12B
MS
12C
MS
12D

FIG. 1

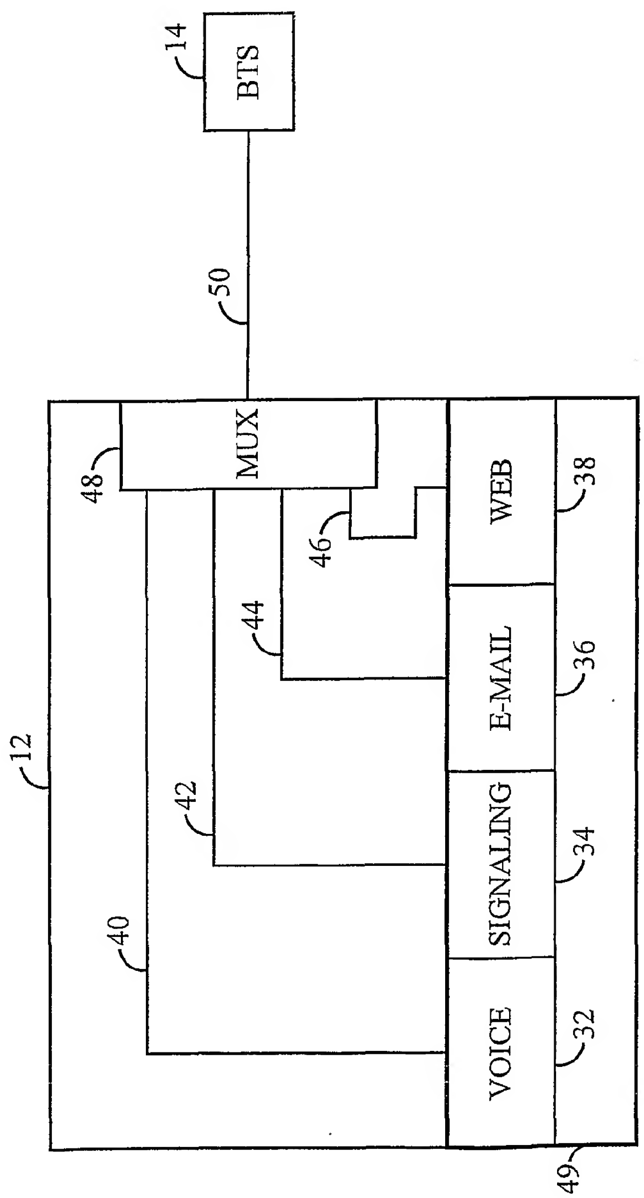

14
BTS
50
12
MUX
48
46
44
42
40
WEB
E-MAIL
SIGNALING
VOICE
38
36
34
32
49

FIG. 2

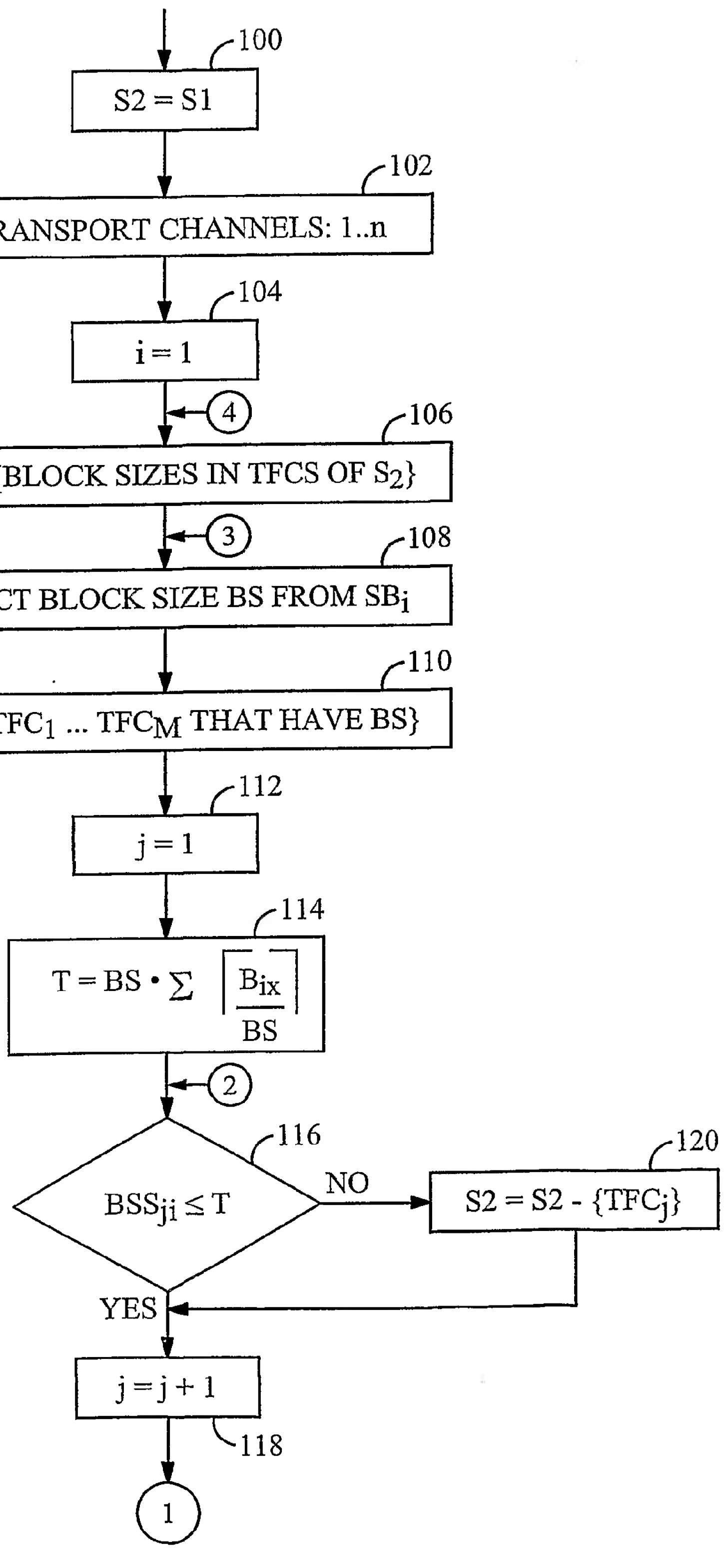

100
S2 = S1
102
N TRANSPORT CHANNELS: 1..n
104
i = 1
4
106
SBi = {BLOCK SIZES IN TFCS OF S2}
3
108
SELECT BLOCK SIZE BS FROM SBi
110
ST = {TFC1 ... TFCM THAT HAVE BS}
112
j = 1
114
T = BS • Σ ⌈Bix / BS⌉
2
116
BSSji ≤ T
NO
120
S2 = S2 - {TFCj}
YES
j = j + 1
118
1

FIG. 3A

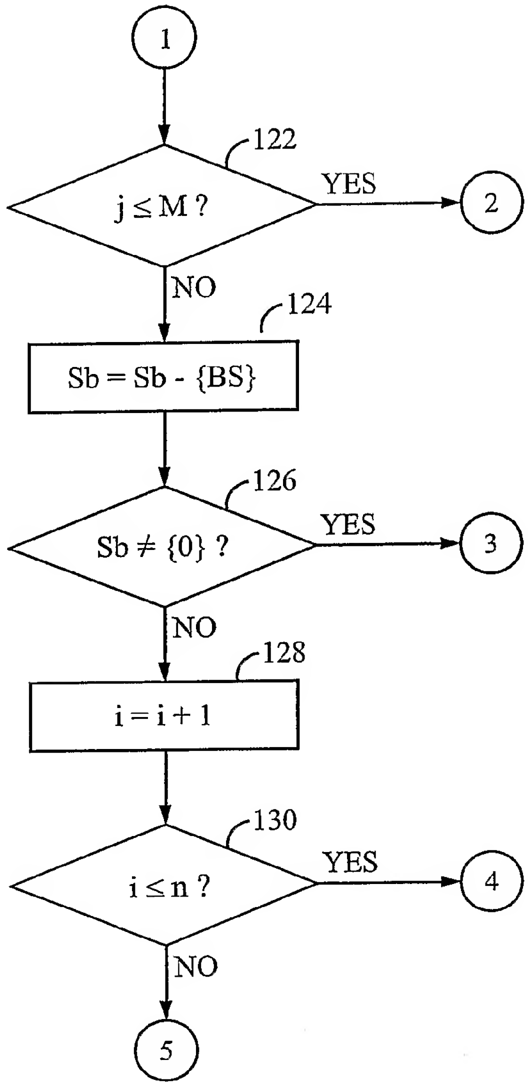

1
122
j ≤ M ?
YES
2
NO
124
Sb = Sb - {BS}
126
Sb ≠ {0} ?
YES
3
NO
128
i = i + 1
130
i ≤ n ?
YES
4
NO
5

FIG. 3B

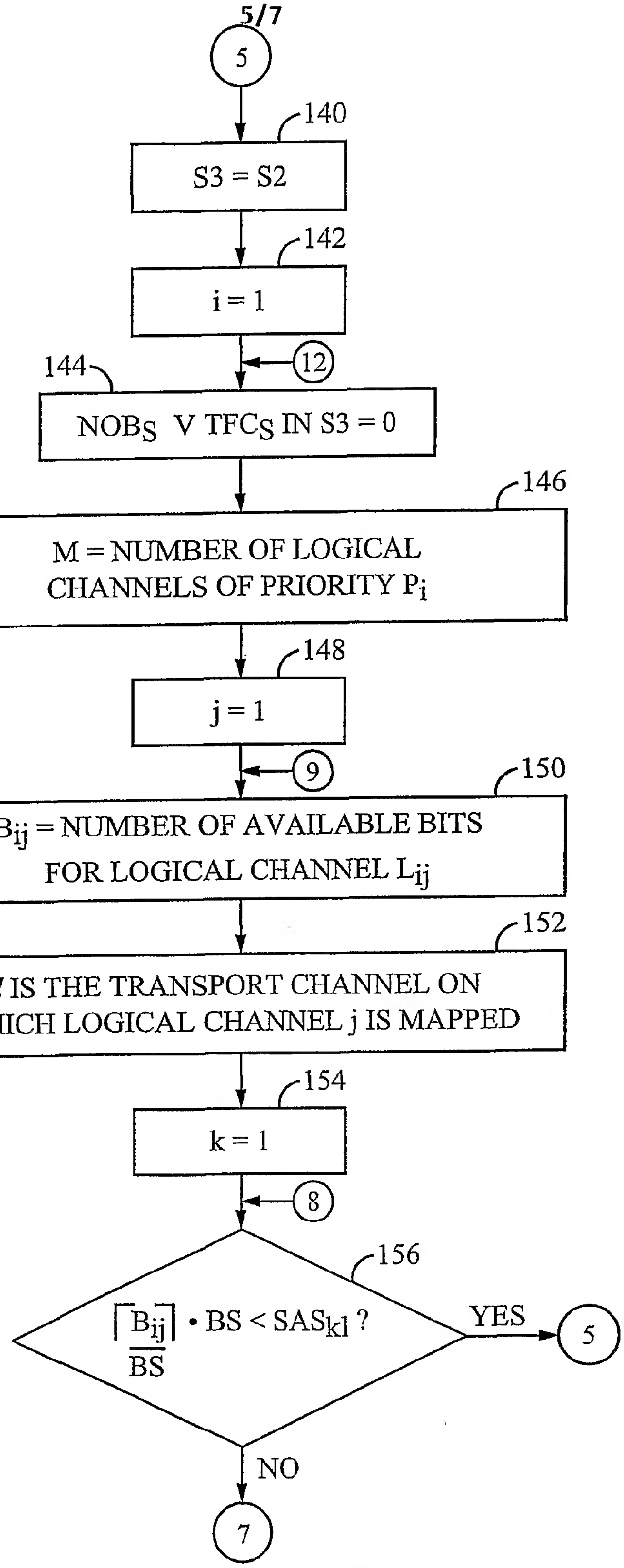

5
140
S3 = S2
142
i = 1
12
144
NOBS V TFCS IN S3 = 0
146
M = NUMBER OF LOGICAL CHANNELS OF PRIORITY Pi
148
j = 1
9
150
Bij = NUMBER OF AVAILABLE BITS FOR LOGICAL CHANNEL Lij
152
l IS THE TRANSPORT CHANNEL ON WHICH LOGICAL CHANNEL j IS MAPPED
154
k = 1
8
156
⌈Bij/BS⌉ • BS < SASkl ?
YES
5
NO
7

FIG. 4A

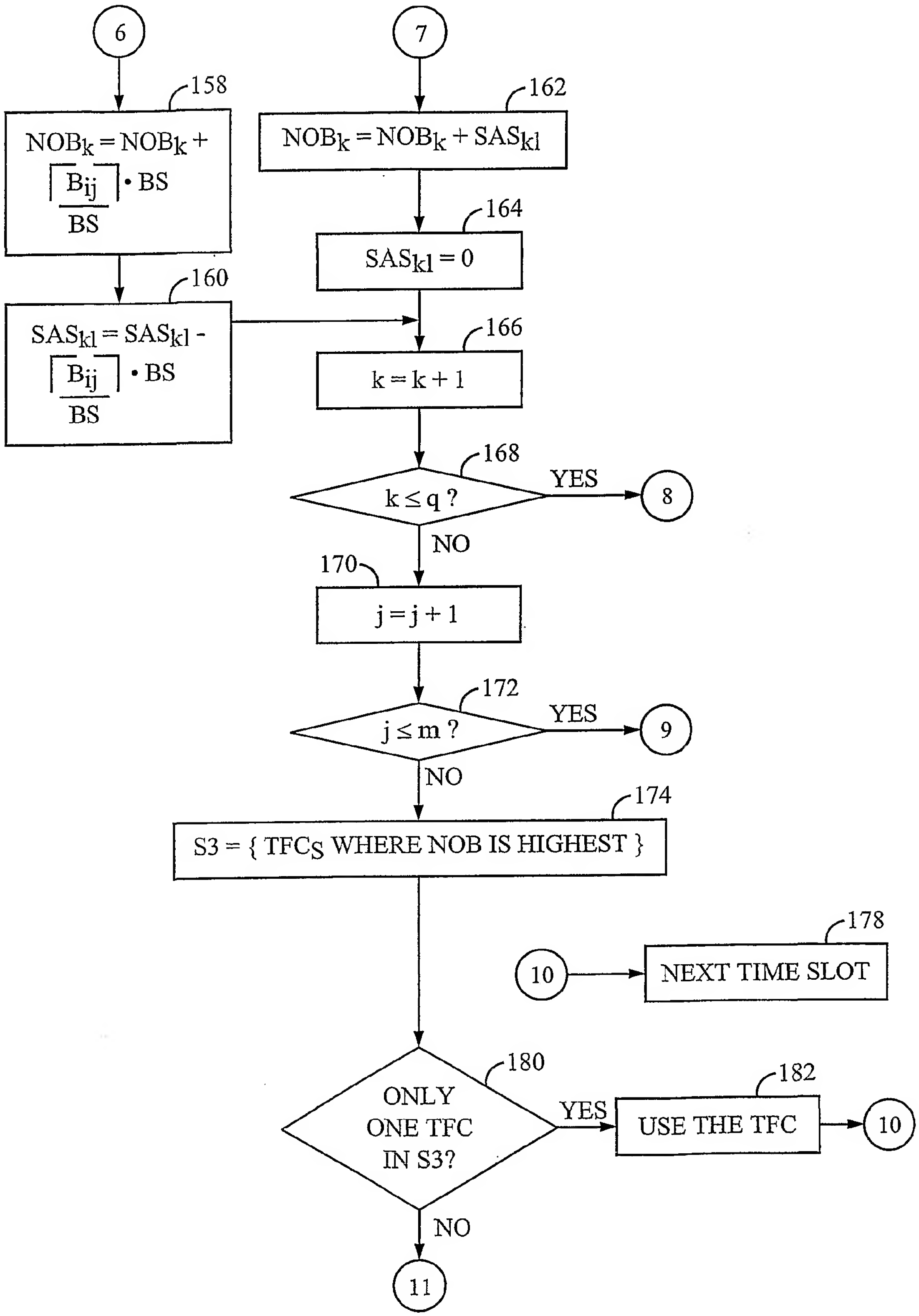

6
7
158
$NOB_k = NOB_k + \left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS$
162
$NOB_k = NOB_k + SAS_{kl}$
164
$SAS_{kl} = 0$
160
$SAS_{kl} = SAS_{kl} - \left\lceil \frac{B_{ij}}{BS} \right\rceil \cdot BS$
166
$k = k + 1$
168
$k \leq q$?
YES
8
NO
170
$j = j + 1$
172
$j \leq m$?
YES
9
NO
174
S3 = { TFC_S WHERE NOB IS HIGHEST }
178
10
NEXT TIME SLOT
180
ONLY ONE TFC IN S3?
YES
182
USE THE TFC
10
NO
11

FIG. 4B

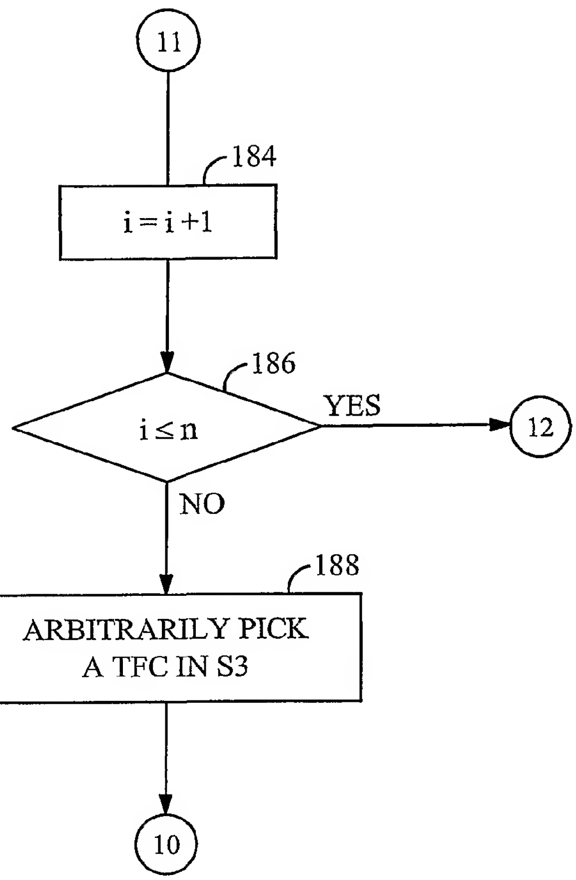


FIG. 4C

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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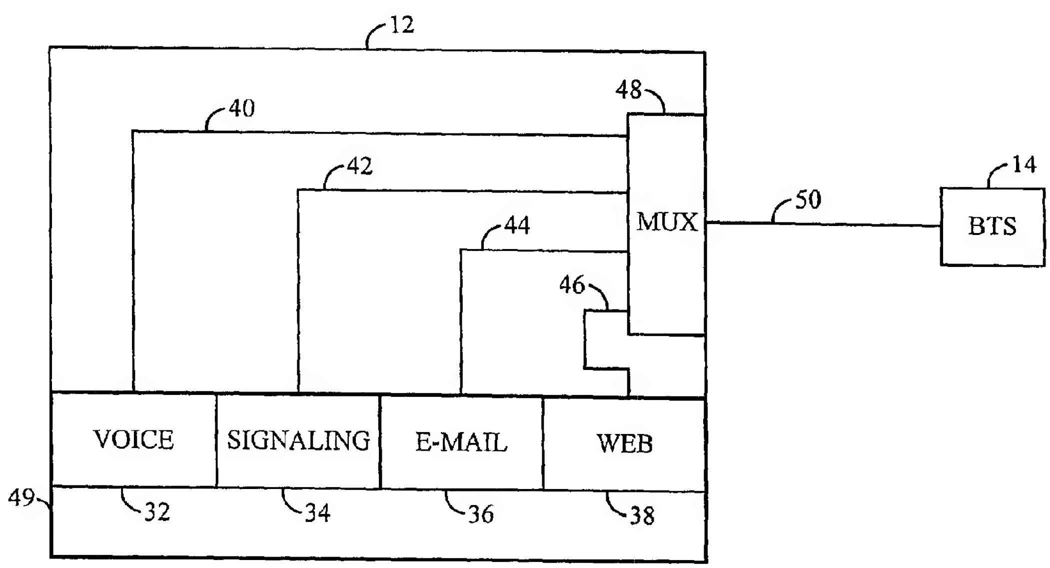
[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR ALLOCATING DATA STREAMS ONTO A SINGLE CHANNEL



(57) Abstract: A method and system that enables multiplexing a plurality of data streams onto one data stream based on data stream priorities and available transport frame combinations (TFCs) is disclosed. A mobile station 12 has applications that produce separate data streams. Example applications include voice 32, signaling 34, E-mail 36 and web applications 38. The data streams are combined by a multiplexer module 48 into one data stream called the transport stream 50. The transport stream 50 is sent over the reverse link to base station transceivers (BTS) 14. The multiplexer module 48 multiplexes the data streams onto the transport stream according to their priorities and the available TFCs.

WO 02/041531 A3

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 001 642 A (MITSUBISHI ELECTRIC INF TECH) 17 May 2000 (2000-05-17) column 4, line 6 - line 51 column 4, line 56 -column 5, line 46 column 7, line 11 - line 34 column 10, line 50 -column 11, line 4 ---	1-55
A	WO 00 28760 A (NOKIA NETWORKS OY ;RINNE MIKKO (FI); SALONEN JANNE (FI); AHMAVAARA) 18 May 2000 (2000-05-18) page 11, line 19 - line 30 page 13, line 11 -page 14, line 14 ---	1-55
A	WO 99 66736 A (NOKIA MOBILE PHONES LTD ;TURUNEN MATTI (FI); KALLIOKULJU JUHA (FI)) 23 December 1999 (1999-12-23) page 1, line 23 - line 35 page 5, line 15 - line 26; figure 2 --- -/--	1-55

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 July 2002	10/07/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Sorrentino, A

2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/45350

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 991 218 A (LG ELECTRONICS INC) 5 April 2000 (2000-04-05) column 2, line 48 -column 3, line 23 column 4, line 11 - line 31 -----	1-55

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 01/45350

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1001642 A	17-05-2000	FR 2785758 A1	12-05-2000
		EP 1001642 A1	17-05-2000
WO 0028760 A	18-05-2000	FI 982417 A	07-05-2000
		AU 1273800 A	29-05-2000
		BR 9915079 A	17-07-2001
		CN 1325601 T	05-12-2001
		EP 1125460 A2	22-08-2001
		WO 0028760 A2	18-05-2000
WO 9966736 A	23-12-1999	FI 981401 A	17-12-1999
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		EP 1095489 A2	02-05-2001
		WO 9966736 A2	23-12-1999
EP 0991218 A	05-04-2000	EP 0991218 A2	05-04-2000

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(72) Inventors: **PANKAJ, Rajesh**; 7356 Park Village Road, San Diego, CA 92129 (US). **LUNDBY, Stein**; 716 North Granados Avenue, Solana Beach, CA 92075 (US). **YAFUSO, Byron**; 10093 Branford Road, San Diego, CA 92129 (US).

(74) Agents: **WADSWORTH, Philip, R.** et al.; Qualcomm Incorporated, 5775 Morehouse Drive, San Diego, CA 92121-1714 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(54) Title: METHOD AND APPARATUS FOR TRANSMITTING MESSAGES IN A WIRELESS COMMUNICATION SYSTEM.

(57) Abstract: Techniques to reduce transmit power required for transmission of messages from an access terminal to reduce interference to transmissions from other access terminals. In one aspect, messages to be transmitted are defined and/or coded such that they may be detected at different received signal qualities. The codewords may be defined having different distances to their nearest codewords. In another aspect, messages to be transmitted are assigned to different points in a signal constellation, with the points being located such that they may be received at different signal qualities. Codewords that may be received at a lower signal quality may be assigned to messages more likely to be transmitted at higher transmit power levels (e.g., when the access terminal is located further away) or to more frequently transmitted messages.

METHOD AND APPARATUS FOR TRANSMITTING MESSAGES IN A WIRELESS COMMUNICATION SYSTEM

BACKGROUND

I. Field

The present invention relates to data communication. More particularly, the present invention relates to a novel and improved method and apparatus for transmitting messages in a wireless communication system.

II. Description of the Related Art

Wireless communication systems are widely deployed to provide various types of communication such as voice, data, and so on. These systems may be based on code division multiple access (CDMA), time division multiple access (TDMA), or some other modulation techniques. A CDMA system provides certain advantages over other types of system, including increased system capacity.

A CDMA system may be designed to support one or more CDMA standards such as (1) the "TIA/EIA-95-B Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" (the IS-95 standard), (2) the "TIA/EIA-98-C Recommended Minimum Standard for Dual-Mode Wideband Spread Spectrum Cellular Mobile Station" (the IS-98 standard), (3) the standard offered by a consortium named "3rd Generation Partnership Project" (3GPP) and embodied in a set of documents including Document Nos. 3G TS 25.211, 3G TS 25.212, 3G TS 25.213, and 3G TS 25.214 (the W-CDMA standard), (4) the standard offered by a consortium named "3rd Generation Partnership Project 2" (3GPP2) and embodied in a set of documents including "TR-45.5 Physical Layer Standard for cdma2000 Spread Spectrum Systems," the "C.S0005-A Upper Layer (Layer 3) Signaling Standard for cdma2000 Spread Spectrum Systems," and the "C.S0024 cdma2000 High Rate Packet Data Air Interface Specification" (the cdma2000 standard), and (5) some other standards. These standards are incorporated herein by reference. A system that implements the High Rate Packet Data specification of the cdma2000 standard is referred to herein as a high data rate (HDR) system. Proposed wireless systems also provide a combination of HDR and low data rate services (such as voice and fax services) using a single air interface.

In a wireless communication system, the transmit power required for a transmission is dependent on the propagation (or path) loss between a transmitting entity (e.g., an access terminal) and a receiving entity (e.g., an access point). As an access terminal moves further away from the access point, the path loss typically increases. Consequently, more transmit power is required so that the transmission can be received at the required signal quality for the desired level of performance (e.g., one percent frame error rate). However, the higher transmit power for this transmission causes more interference to the transmissions from other access terminals. The higher transmit power also causes faster depletion of battery power on mobile wireless devices. There is therefore a need in the art for a way to provide HDR services that minimizes interference and depletion of battery power.

SUMMARY

The disclosed embodiments provide techniques to reduce the amount of transmit power required for transmission of selected messages from an access terminal. In a first aspect, the reduction in transmit power is based on the expected path loss associated with the reverse link, thus tending to extend the operating range of an HDR access terminal, and at the same time decreasing reverse link interference in adjacent cells. In another aspect, the reduction in transmit power is based on the relative frequency with which an HDR access terminal is expected to send each type of message, thus tending to minimize reverse link interference in a serving cell. Both of these aspects also have the benefit of tending to extend battery life of a mobile wireless device such as a mobile HDR access terminal. The techniques described herein can also be applied to forward link transmissions from an access point. Various other aspects of the invention are also presented.

The invention provides methods and system elements that implement various aspects, embodiments, and features of the invention, as described in further detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, nature, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a diagram of a wireless communication system that supports a number of users, and which can implement various aspects of the invention;

FIG. 2 is a diagram of a packet transmission scheme used in the HDR system;

FIG. 3 is a block diagram of a reverse link architecture employed in the HDR system and capable of transmitting Data Rate Control (DRC) messages and other information;

FIGS. 4A and 4B are diagrams graphically illustrating an alphabet of codewords having equal distance and unequal distances, respectively, to the nearest codewords;

FIGS. 5A and 5B are diagrams of two signal constellations having points selected from different modulation formats;

FIG. 6A is a block diagram of an embodiment of an access terminal, in accordance with various aspects of the invention; and

FIG. 6B is a block diagram of an embodiment of a portion of a transmit (TX) data processor, which may be used to process DRC messages for various schemes described herein.

DETAILED DESCRIPTION OF THE SPECIFIC EMBODIMENTS

FIG. 1 is a diagram of a wireless communication system 100 that supports a number of users, and which can implement various aspects of the invention. System 100 may be designed to support one or more CDMA standards and/or designs (e.g., the cdma2000 standard, the HDR specification). For simplicity, system 100 is shown to include three access points 104 (which may also be referred to as base stations) in communication with two access terminals 106 (which may also be referred to as remote terminals or mobile stations). The access point and its coverage area are often collectively referred to as a "cell".

Depending on the CDMA system being implemented, each access terminal 106 may communicate with one (or possibly more) access points 104 on the forward link at any given moment, and may communicate with one or more access points on the reverse link depending on whether or not the access terminal is in soft handoff. The forward link (i.e., downlink) refers to transmission from the access point to the access terminal, and the reverse link (i.e., uplink) refers to transmission from the access terminal to the access point.

In a CDMA system, the cells may be operated on the same frequency band (i.e., with a frequency reuse of one, or K=1) to achieve better utilization of

the available system resources. In this case, the transmission from each transmitting entity (e.g., access terminal) acts as interference to the transmissions from other transmitting entities. To minimize interference and increase system capacity on the reverse link, the transmit power of each transmitting access terminal is controlled such that a desired level of performance (e.g., one percent frame error rate, or 1% FER) is achieved while minimizing the amount of interference to other transmitting access terminals. This transmit power adjustment is achieved by a power control loop maintained for each transmitting access terminal. The power control loop adjusts the transmit power level of the access terminal such that a transmission is received by the access point at a target signal quality (i.e., a particular signal-to-noise-plus-interference, C/I) needed for the desired level of performance.

In the example shown in FIG. 1, access terminal 106a is located near access point 104a, and access terminal 106b is located near the cell boundaries of access points 104a, 104b, and 104c. For this example, both access terminals are using the same coding and modulation to transmit. Since access terminal 106a is located (relatively) close to access point 104a, its transmit power may be adjusted to a (relatively) low level to achieve the desired level of performance at access point 104a. This low transmit power is possible since the path loss is approximately proportional to the 4^{th} law of the distance between the transmitting and receiving entities (i.e., path loss $\propto$ $(\text{distance})^4$). Because of the low transmit power level and further because of the greater distances between access terminal 106a and access points 104b and 104c, the transmission from access terminal 106a causes little interference to other transmissions received at access points 104b and 104c.

In contrast, access terminal 106b is located further away from access points 104a, 104b, and 104c. Due to the longer distances to these access points, the transmit power of access terminal 106b is likely to be adjusted to a high level to achieve the same level of performance. Because of the high transmit power level and the shorter distances between access terminal 106b and access points 104b and 104c, the transmission from access terminal 106b is likely to cause more interference to other transmissions received at access points 104b and 104c.

As seen by the above example, when an access terminal is located near an access point, less transmit power is required for a transmission, and the transmission causes little interference at other access points. In contrast, when an access terminal is located further away from an access point, more transmit

power is required for a transmission, and the transmission causes more interference at other access points.

Various techniques are provided herein to reduce the amount of transmit power required for transmission of messages from an access terminal, which then results in less interference to the transmissions from other access terminals. Some of these techniques are briefly described below.

In one aspect, messages to be transmitted from an access terminal are defined and/or coded such that they may be received by an access point at different received signal qualities. In one implementation, an alphabet of codewords is defined whereby at least some of the codewords have different "distances" to their nearest codewords (i.e., different minimum distances, d_{min}). As used herein, an "alphabet" is a collection of individual codewords, each of which (1) is represented by a specific value or sequence of bits, (2) may be associated with a particular meaning by a system (e.g., a particular data rate), and (3) is selectable for transmission as all or a part of a message. For digital codes, minimum distance, d_{min}, relates to the minimum number of bit errors in a received codeword necessary to cause an equal or greater correlation with an incorrect codeword. Minimum distance, d_{min}, may also refer to the distance between points in a (typically multi-dimensional) signal constellation. A codeword with a larger minimum distance may be correctly detected at a lower signal quality, and a codeword with a smaller minimum distance typically requires higher signal quality for proper reception.

In certain embodiments, codewords with larger minimum distances may be advantageously assigned to messages more likely to be transmitted by access terminals located further away from the access point, which would normally need to transmit their messages at higher transmit power levels due to greater path loss. This alphabet and codeword assignment scheme allow access terminals to transmit their messages using less power when located further away from the access point, which then reduces the amount of interference to transmissions from other access terminals in adjacent cells and may further extend the range of the access terminal.

In some other embodiments, codewords with larger minimum distances may be advantageously assigned to more frequently transmitted messages. Since these messages may be received at a lower signal quality, they cause less interference to messages from other transmitting access terminals. The reduced interference may increase the capacity of the reverse link.

In another aspect, messages to be transmitted are assigned to different points in a signal constellation. In such an aspect, d_{min} refers to the distance

between a point on the signal constellation and the nearest other point in the same signal constellation. The points in the signal constellation may be viewed as codewords in an alphabet, and may be selected from various modulation formats such as quadrature phase shift keying (QPSK), M-ary phase shift keying (e.g., 8-PSK), quadrature amplitude modulation (e.g., 16-QAM, 64-QAM), and others. A custom signal constellation may also be generated having points at various defined locations. The location of the points in the signal constellation may be defined such that the points may be received at different signal qualities (i.e., the points have different distances to their nearest neighbor points). In certain embodiments, messages expected to be transmitted at higher transmit power level (e.g., from an access terminal located further away from an access point and having greater path loss) are assigned to points that may be received at lower signal qualities, and thus may be transmitted at lower transmit power. And in some other embodiments, more frequently transmitted messages are assigned to points that may be received at lower signal qualities, which may result in less interference and increased link capacity.

In yet another aspect, the transmit power used to transmit a message is adjusted by varying the length of the codeword used, and hence the length of the transmit duration. For example, messages to be transmitted from an access terminal are defined with different lengths. In one implementation, an alphabet of codewords is defined whereby at least some of the codewords have different lengths. For a given link condition, a shorter length codeword may be transmitted at the same transmit power level but over a shorter time interval relative to a longer length codeword, or at a lower transmit power level over the same time interval. Shorter length codewords may be assigned to messages more likely to be transmitted by an access terminal located further away from an access point, which would tend to reduce the amount of interference in the system. Alternatively or additionally, shorter length codewords may be assigned to more commonly transmitted messages, which would also tend to extend the battery life of the access terminal.

The message transmission schemes described herein may be used for any set of defined messages to be transmitted on any channel on the forward or reverse link. These message transmission schemes may also be used for other wireless communication systems and for other CDMA systems that may support one or more other CDMA standards and/or designs.

For clarity, various aspects, embodiments, and features of the invention are now described for a specific implementation in conjunction with a Data Rate Control (DRC) channel defined for the reverse link in a High Data Rate (HDR)

system. The disclosed aspects and embodiments may be equally applied to other types of system, such as a hybrid system that supports high rate packet data services and voice services concurrently or other types of systems mentioned above.

In the HDR system, each access point transmits packet data to access terminals within its coverage, one at a time, in a time-division multiplexed manner. An access point transmits packet data to an access terminal at or near the peak transmit power level, if at all. Whenever an access terminal desires a data transmission, it sends a packet data request in the form of a DRC message to a selected access point. The access terminal measures the signal quality of the forward link signals (e.g., the pilot references) received from a number of access points, determines the access point having the best received signal quality, identifies the highest data rate supported by the best received link, and sends a DRC message indicative of the identified data rate. This DRC message is transmitted on the DRC channel and directed to the selected access point associated with the best received signal quality. The selected access point receives the DRC message and schedules a data transmission for the access terminal at the identified data rate.

As shown in FIG. 1, access terminal 106a is located (relatively) close to access point 104a and likely to experience smaller path loss. To maintain the desired level of performance while minimizing interference to other transmitting access terminals, the transmission from each access terminal is power controlled such that it is received at the target signal quality needed for the desired level of performance. Because of the smaller path loss, access terminal 106a is able to transmit the DRC message for the identified data rate at a lower transmit power level and still be received by the access point at the target signal quality. In contrast, access terminal 106b is located further away from access point 104a and likely to experience greater path loss. Because of the greater path loss, access terminal 106b is required to transmit the DRC message at a higher transmit power level to achieve the target signal quality

FIG. 2 is a diagram of a packet transmission scheme used in the HDR system. Initially, a request for a data transmission is received from an access terminal. In response, one or more Physical Layer packets are generated by an access point and transmitted to the access terminal starting at time slot n. Each packet includes a particular number of data bits (e.g., 1024 bits in the HDR system) and may be transmitted as one or more "slots". The number of slots for each packet is dependent on the data rate, and four slots are included in the example packet shown in FIG. 2. For each slot, the access terminal receives and

processes (e.g., decovers, demodulates, deinterleaves, and decodes) the slot, and further determines whether the packet has been received correctly. The access terminal is able to recover the transmitted packet based on a partial transmission because the data modulation symbols generated for the packet are repeated a number of times for lower data rates and transmitted.

In an HDR system, each access terminal desiring a data transmission continually measures the received quality of forward link signals received from one or more access points. The access terminal then directs DRC messages to the access point having the best measured forward link signal quality. The DRC message transmission continues until the requested data transmission is successfully received by the access terminal. A portion of the reverse link capacity is utilized for this continual transmission of DRC messages by access terminals requesting data transmissions.

In an exemplary embodiment, a DRC message identifies the particular access point from which data is being requested, and also indicates the data rate at which that data should be transmitted, if at all. An access point receives DRC requests from multiple access terminals during each time slot, but transmits to only one access terminal per time slot. Because the access terminal might not receive a forward link transmission in response to each DRC message, the access terminal continuously sends DRC messages in every time slot. If the access terminal fails to send a DRC message in a reverse link time slot, it will generally not receive any forward link data in the corresponding forward link time slot.

FIG. 3 is a block diagram of a reverse link architecture employed in the HDR system and capable of transmitting DRC messages and other information (e.g., pilot, reverse rate indicator (RRI), acknowledgment (ACK), and packet data). Examples of such signal structures are described in detail in the aforementioned cdma2000 standard. For simplicity, only the processing for the DRC message is described herein. The HDR system supports a number of different data rates for data transmission on the forward link. Each of the supported forward link data rates is associated with a respective DRC value. In the cdma2000 standard, each of 16 possible DRC values is represented by a 4-bit value. A DRC processor 330 receives the DRC value for the identified data rate, which represents a message to be transmitted, and provides a code sequence for the message.

Within DRC processor 330, the DRC value is mapped to an assigned 8-bit bi-orthogonal codeword (or DRC codeword) by a bi-orthogonal encoder 332. The 8-bit DRC codeword is then repeated twice in block 334 to generate 16

binary symbols to be transmitted per active slot. The binary symbols are then mapped (e.g., "0" → +1, and "1" → -1) by a signal mapping element 336. Each mapped binary symbol is further covered by a coverer 338 with a particular 8-ary Walsh function, W_i^8, provided by a Walsh cover generator 340. This Walsh function, W_i^8, is the one assigned to the selected access point having the best link to the access terminal.

The 16 binary symbols in the two repeated DRC codewords are used to generate 128 Walsh chips by coverer 338. Each Walsh chip is further covered by a coverer 342 with a 16-bit Walsh function, W_8^{16} (i.e., a sequence of "1111111100000000"). The 128 Walsh chips from coverer 338 for each active slot are thus covered to generate 2048 chips. The sequence of 2048 chips for the DRC message is then combined with other data within a combiner and modulator 350, modulated, and transmitted over one time slot, which is defined as 1.667 msec in the cdma2000 standard.

Table 1 lists the 16 DRC values and their corresponding DRC codewords, as defined in the cdma2000 standard. As noted above, the DRC values are representative of the forward link data rates, with the mapping between the data rates and DRC values being defined in the cdma2000 standard.

Table 1

DRC Value	DRC Codeword	DRC Value	DRC Codeword
0	0000 0000	8	0000 1111
1	1111 1111	9	1111 0000
2	0101 0101	10	0101 1010
3	1010 1010	11	1010 0101
4	0011 0011	12	0011 1100
5	1100 1100	13	1100 0011
6	0110 0110	14	0110 1001
7	1001 1001	15	1001 0110

lists the 8-ary Walsh functions, W_i^8, that may be assigned to the access points. By covering the DRC codeword for the identified data rate with the specific Walsh function, W_i^8, assigned to the selected access point, the selected and neighbor access points are able to easily determine whether or not the DRC message has been sent to them. Only the access point assigned with that Walsh function, W_i^8, processes the DRC message for scheduling data to the access terminal.

Table 2

Walsh Function	Walsh Sequence	Walsh Function	Walsh Sequence
W_0^8	0000 0000	W_4^8	0000 1111
W_1^8	0101 0101	W_5^8	0101 1010
W_2^8	0011 0011	W_6^8	0011 1100
W_3^8	0110 0110	W_7^8	0110 1001

Referring back to Table 1, the DRC codewords are selected such that each codeword (e.g., "0000 0000") differs from its compliment (e.g., "1111 1111") by eight bit positions, and further differs from all other codewords by four bit positions. For this "alphabet" of 16 DRC codewords, the minimum distance, d_{min}, between the codewords is equal to four. For a transmitted DRC codeword, an access point is able to correctly detect the codeword if fewer than $d_{min}/2$ bits in the codeword are received in error. Otherwise, if $d_{min}/2$ or more bits are received in error, the codeword may be erroneously detected.

In accordance with an aspect of the invention, an alphabet of codewords is defined such that at least some of the codewords have a variety of different minimum distances. For this alphabet, the minimum distances for some codewords are smaller than average while the minimum distances for some other codewords are larger than average. A codeword with a smaller minimum distance must be received at a higher power level to achieve a higher C/I needed for the desired level of performance (e.g., 1% FER). Correspondingly, a codeword with a larger minimum distance may be received at a lower power level since a lower C/I is required for the same level of performance.

In certain embodiments, codewords with larger minimum distances are assigned to messages more likely to be sent by access terminals which would have required higher transmit power levels (e.g., by access terminals located further away from the access point and experiencing greater path loss). In other embodiments, codewords with smaller minimum distances are assigned to more frequently transmitted messages.

FIG. 4A is a diagram graphically illustrating an alphabet of codewords having equal minimum distance to the nearest codewords. In this example, the codewords are represented as points 412 equally spaced on a circle 410 in a 2-D plane. Because of the equal spacing, the distance between any pair of adjacent codewords is d_A. The distance from the center of circle 410 and any particular point 412 can be representative of the transmit power (P_S) for the point, and the distance from this point outward (i.e., toward the edge of a circle 414) can be

representative of noise (P_N). In this example, any codeword may be correctly received if the noise is less than $d_A/2$ (i.e., $P_N < d_A/2$). If the noise is greater than or equal to $d_A/2$, the codeword may be erroneously detected as another codeword (i.e., an adjacent codeword). Because of the equal codeword spacing, the codewords in this alphabet are equally susceptible to noise. Thus, the same received signal quality (C/I) is required for each codeword for a particular desired level of performance.

FIG. 4B is a diagram graphically illustrating an alphabet of codewords having unequal distances to the nearest codewords. In this example, the codewords are represented as points 422 unequally spaced on a circle 420 in the 2-D plane. The eight codewords are spaced such that the distance between each pair of adjacent codewords ranges from d_{B1} to d_{B4}, where $d_{B1} < d_{B2} < d_{B3} < d_{B4}$. Codeword A has the smallest distance, d_{B1}, to the nearest codewords B and H, and is more susceptible to noise. This codeword may be correctly received if the noise is less than $d_{B1}/2$ (i.e., $P_{NA} < d_{B1}/2$). Consequently, a higher received signal quality (C/I) is needed for the desired level of performance.

In contrast, codeword E has the largest distance, d_{B4}, to the nearest codewords D and F, and is less susceptible to noise. This codeword may be correctly received if the noise is less than $d_{B4}/2$ (i.e., $P_{NE} < d_{B4}/2$). Thus, a lower received signal quality is needed for the same level of performance, which allows this codeword to be transmitted at a lower transmit power level.

The examples of FIGS. 4A and 4B were chosen because they are easy to graphically illustrate on a flat sheet of paper. A person skilled in the art will appreciate that the same principles also apply to coding over any other single or multi-dimensional spaces where a distance metric can be defined.

Referring back to FIG. 1, access terminal 106a is located (relatively) close to access point 104a. Because of the smaller path loss, access terminal 106a is likely to request transmission at a high data rate (e.g., 614.4 kbps or higher) from this access point. In contrast, access terminal 106b is located further away from access point 104a. Because of the greater path loss, access terminal 106a is likely to request transmission from this access point at a lower data rate (e.g., 76.8 kbps or lower).

If, as is the case in the cdma2000 standard, the minimum distance between the DRC codewords is relatively uniform, then all codewords must be transmitted by the access terminals such that they are received by the access point at the target signal quality. This is achieved by controlling the transmit power such that codewords from access terminals with greater path loss are transmitted at higher transmit power levels, and codewords from access

terminals with smaller path loss are transmitted at lower transmit power levels. For the example shown in FIG. 1, if both access terminals 106a and 106b concurrently request data transmission from access point 104a, access terminal 106b would transmit its DRC message at a higher transmit power level than would access terminal 106a to achieve the target received signal quality at access point 104a.

The path loss versus distance is approximately equal for the forward and reverse links. Consequently, a DRC message for a progressively lower data rate is (disadvantageously but necessarily) transmitted at a progressively higher transmit power level. This could cause more interference to reverse link signals of cells adjacent to access point 104a. The higher transmit power for a longer time period may further shorten the access terminal's operating life if it is a mobile unit operating on battery power.

Table 3 lists an alphabet whereby at least some of the codewords have unequal minimum distances, and which may be used for the DRC messages. In this example, the alphabet includes 16 codewords {A, B, ... P} assigned to the 16 DRC values {0, 1, ... 15}. These 16 codewords may be used for up to 16 data rates $\{R_0, R_1, \ldots R_{15}\}$. Each codeword in the alphabet has a particular distance d_X to the nearest codeword (i.e., a particular minimum distance), which is listed in columns 4 and 8 of Table 3.

Table 3

DRC Value	Data Rate	Code-word	Minimum Distance	DRC Value	Code-word	Data Rate	Minimum Distance
0	R_0	A	d_0	8	I	R_8	d_8
1	R_1	B	d_1	9	J	R_9	d_9
2	R_2	C	d_2	10	K	R_{10}	d_{10}
3	R_3	D	d_3	11	L	R_{11}	d_{11}
4	R_4	E	d_4	12	M	R_{12}	d_{12}
5	R_5	F	d_5	13	N	R_{13}	d_{13}
6	R_6	G	d_6	14	O	R_{14}	d_{14}
7	R_7	H	d_7	15	P	R_{15}	d_{15}

In an embodiment, the codewords for the alphabet are defined such that the minimum distances for the codewords maintain the following relationships:

$$d_0 \geq d_1 \geq d_2 \geq \ldots \geq d_{13} \geq d_{14} \geq d_{15}\text{, and}$$

$$d_0 > d_{15}\ .$$

As shown by the above relationships, at least some (and not necessarily all) of the codewords in the alphabet have different minimum distances.

In certain embodiments, the codewords in the alphabet are assigned such that messages more likely to be transmitted at higher transmit power levels are assigned to codewords having larger minimum distances. As noted above, for the DRC messages, progressively higher transmit power levels are typically needed for progressively lower data rates. Thus, in an embodiment, the codewords are assigned to the data rates such that codewords with progressively larger minimum distances are assigned to progressively lower data rates. For the codeword assignment shown in Table 3, the data rates may be defined to maintain the following relationship:

$$R_0 \leq R_1 \leq R_2 \leq \ldots \leq R_{13} \leq R_{14} \leq R_{15} .$$

Based on the above alphabet and codeword assignment, an access terminal located further away from an access point is likely to request data transmission at a lower data rate, which would be assigned with a codeword having a larger minimum distance. This codeword may then be transmitted at a lower relative transmit power level than would otherwise be required for a codeword with an average minimum distance.

The above embodiment can be extended to any type of transmission on the forward link where different codewords correspond to transmissions requiring different C/I. Codeword assignment based on data rates is applicable for the HDR system because, to be received with equal quality, low data rates require lower C/I than high data rates. Thus, the HDR system assigns lower data rates to users located far from the access point. The codeword assignment can be based on the required C/I in some other manner. For example, a particular system may assign all users the same data rate, but different spreading codes. If the spreading codes are not the same, the users close to the access point can be assigned (not quite as good) spreading codes that are more susceptible to be interfered than the ones assigned to users located far away. The same concept can be applied to an FDMA system, where some frequency bands (e.g., unlicensed frequency bands) have more interference than others.

In some other embodiments, codewords in the alphabet are assigned such that messages more frequently transmitted are assigned to codewords having larger minimum distances. This allows commonly transmitted messages to be transmitted at lower power levels, which may reduce interference and increase link capacity.

In the above-described HDR system, the 8-bit DRC code word is repeated and covered twice to generate 2048 chips for each active time slot. For an alphabet having codewords with different minimum distances, the codewords can be defined to have lengths of 8, 16, 32, 64, and so on, up to 2048 bits. Longer codeword length generally provides more flexibility in selecting a set of codewords having varying minimum distances. Codewords of any length may be used and are within the scope of the invention.

Table 4 shows an example of a simple alphabet with four codewords having different distances to the nearest codewords. In this example alphabet, codeword A has distances of 4, 3, and 3 to codewords B, C, and D, respectively. Codeword B has distances of 4, 1, and 1 to codewords A, C, and D, respectively. Because of the larger distance to other codewords in the alphabet, codeword A may be correctly received at a lower C/I. This allows codeword A to be transmitted at a lower transmit power level. Codeword A may thus be advantageously assigned to the lowest supported data rate (e.g., 38.4 kbps). The remaining codewords may be assigned to the other supported data rates in a similar manner based on their minimum distances.

Table 4

DRC Value	Data Rate	Codeword	Sequence
0	38.4 kbps	A	0000
1	76.8 kbps	B	1111
2	153.6 kbps	C	1110
3	307.2 kbps	D	0111

In accordance with another aspect of the invention, messages to be transmitted are assigned to different points in a signal constellation. The signal constellation may include points from various modulation formats such as, for example, QPSK, 8-PSK, 16-QAM, 32-QAM, 64-QAM, and others. The location of the points in the signal constellation and the assignment of the points to the messages may be dependent on various factors such as, for example, the expected transmit power level for the messages, the frequency of the messages, and so on.

FIG. 5A is a diagram of a signal constellation having seven points selected from two different modulation formats. In this diagram, each point in the signal constellation is associated with a respective message that may be transmitted. In quadrants 1, 2, and 3, QPSK is employed and three different messages are assigned to points 512a, 512b, and 512c. And in quadrant 4, 16-

QAM is employed and four different messages are assigned to points 514a, 514b, 514c, and 514d.

As seen in FIG. 5A, the points are closer to one another as the modulation order increases from QPSK to 16-QAM. The larger distance between points 512a, 512b, and 512c for QSPK results in these points being more immune to erroneous detection due to noise. Note that in the example shown in FIG. 5A, the minimum distance for point 512b is greater than the minimum distance for points 512a and 512c. The points in the constellation need not be arranged in rectangular fashion as shown, but may be arranged in any way that produces the desired relative transmit levels. For example, a double-log scale (i.e., log in the x and y coordinates) may be used to define the points in the constellation to produce approximately even reduction in the minimum distance.

Some QPSK points may be transmitted at a lower transmit power level than others. These QPSK points may be assigned to messages likely to be transmitted at higher transmit power level (e.g., from an access terminal located further away from an access point). Alternatively, the QPSK points may be assigned to more frequently transmitted messages, which would result in less interference at the access point since these messages may be transmitted with less power due to the larger minimum distance. Conversely, the smaller distance between points 514a, 514b, 514c, and 514d for 16-QAM results in these points being more susceptible to erroneous detection due to noise (relative to QPSK). As a result, these 16-QAM points may be transmitted at a higher transmit power level than for the QPSK points.

FIG. 5B is a diagram of a signal constellation having 23 points selected from four different modulation formats. As seen in FIG. 5B, the points are closer to one another as the modulation order increases from QPSK to 8-PSK, to 16-QAM, and to 64-QAM. Again, points with larger distances to neighbor points may be transmitted at lower transmit power level, and may be assigned to messages more likely to be transmitted at higher transmit power (e.g., messages likely to be sent by remote terminals located further away from the access point). Conversely, points with smaller distance to neighbor points are transmitted at higher transmit power level, and may be assigned to messages more likely to be transmitted at lower transmit power (e.g., messages likely to be sent by remote terminals located closer to the access point).

Other signal constellations may also be defined for any set of messages. The points in the signal constellation may be defined such that the distance between any particular point and its nearest neighbor point is based on the

transmit power level expected to be used for that message. Messages expected to be transmitted at higher transmit power level are associated with points having larger distances to the nearest neighbor.

In accordance with yet another aspect of the invention, messages to be sent from an access terminal are associated with codewords having varying lengths. For a particular link condition, the shorter length codewords may be transmitted at the same transmit power level but over shorter time intervals relative to the longer length codewords. The shorter length codewords may also be transmitted at the same transmit power level, but could be repeated and then punctured similar to that performed for the reverse link in the IS-95 system. Alternatively, these shorter length codewords may be transmitted over the same time interval as that of longer length codewords, but at reduced transmit power levels. Shorter length codewords may be assigned to more commonly transmitted messages, which would tend to reduce the amount of interference in the system. Alternatively or additionally, shorter length codewords may be assigned to messages more likely to be transmitted at higher transmit power by access terminals located further away from the access point, which would also tend to reduce the amount of interference. The codewords may be encoded prior to transmission.

The codewords may be defined based on the probability of occurrence of the associated messages. A message with a higher probability of occurrence may be associated with a shorter length codeword, and a message with a lower probability of occurrence may be associated with a longer length codeword. The generation of these codewords may be achieved in a manner similar to that used to generate a Huffman code, which is known in the art and not described herein.

Referring back to FIG. 1, the areas further away from the access points comprise a larger portion of the system's coverage area than the areas near the access points. If the access terminals are equally likely to be located anywhere throughout the coverage area of the system (and even if this is not true), more of the terminals are likely to be located further from the cell. These access terminals are also likely to request data transmissions at lower data rates.

Table 5 lists an example of an alphabet of codewords having varying lengths and assigned to the DRC values. In this example, the DRC values 0 through 15 are assumed to be decreasingly likely to be sent. Thus, the most likely DRC value of 0 is assigned with a codeword having the shortest length of 2, the next most likely DRC value of 1 is assigned with a codeword having the

next shortest length of 3, and so on, and the least likely DRC value of 15 is assigned with a codeword having the longest length of 7.

Table 5

DRC Values	Codeword	DRC Values	Codeword
0	00	8	10110
1	010	9	10111
2	0110	10	110000
3	0111	11	110001
4	1000	12	110010
5	1001	13	110011
6	10100	14	1101000
7	10101	15	1101001

In one embodiment, the shorter length codewords are transmitted within a shorter time period corresponding to their lengths. In another embodiment, the shorter length codewords are transmitted within the same time interval as the longer length codewords (e.g., over an entire time slot), but at reduced transmit power levels. In this case, a codeword may be repeated as many times as necessary to fill the available number of chips in the time slot. The longer transmission period allows the shorter length codeword to be transmitted at a lower power level.

Various processing, coding, and/or transmission schemes may be used in conjunction with the variable-length codewords. These schemes may be employed to increase the likelihood of correctly detecting the codewords or to achieve a particular level of performance.

In one scheme, a variable-length codeword is encoded prior to transmission. The encoding may be achieved based on a convolutional code or some other code known in the art. For a given number of coded bits, a shorter length codeword may be encoded with a stronger code than for a longer length codeword. The stronger code allows the encoded codeword to be correctly received at a lower received signal quality, which may allow the codeword to be transmitted at a lower transmit power level.

FIG. 6A is a block diagram of an embodiment of access terminal 106, which is capable of implementing various aspects of the invention. On the forward link, signals from the access points are received by an antenna 612, routed through a duplexer 614, and provided to an RF receiver unit 622. RF receiver unit 622 conditions (e.g., filters, amplifies, and downconverts) and

digitizes the received signal to provide samples. A demodulator 624 receives and processes (e.g., despreads, decovers, and pilot demodulates) the samples to provide recovered symbols. Demodulator 624 may implement a rake receiver that processes multiple instances of the received signal and generates combined recovered symbols. A receive data processor 626 then decodes the recovered symbols, checks the received frames, and provides the output data.

The samples from RF receiver unit 622 may also be provided to an RX signal quality measurement unit 628 that measures the quality of the received signals from the access points (e.g., based on the received pilots). The signal quality measurement can be achieved using various techniques, including those described in U.S. Patent Nos. 5,056,109 and 5,265,119.

Controller 630 receives the signal quality measurements for the access points, determines the best received link based on the signal quality measurements, determines the data rate supported by the best received link, and determines the codeword associated with the data rate. The codeword is then provided to a transmit data processor 642 for processing and transmission back to the selected access point.

On the reverse link, the message (i.e., codeword) is processed by a transmit (TX) data processor 642, further processed (e.g., spread, modulated) by a modulator (MOD) 644, and conditioned (e.g., converted to analog signals, amplified, filtered, quadrature modulated, and so on) by an RF TX unit 646 to generate a reverse link signal. The reverse link signal is then routed through duplexer 614 and transmitted via antenna 612 to the access points.

FIG. 6B is a block diagram of an embodiment of a portion of TX data processor 642, which may be used to process DRC messages for various schemes described herein. Within a DRC processor 660, a DRC value for a DRC message (or DRC symbol) is mapped to an assigned codeword by a codeword look-up element 662. The mapped codeword may be one of a number of codewords with different minimum distances or different lengths. Alternatively, the mapped codeword may be representative of a particular point in a signal constellation. Depending on the particular implementation, the mapped codeword may be repeated and/or punctured by a repetition/puncture element 664. For some implementations, repetition/puncture element 664 is not used and may be omitted from DRC processor 660.

The codeword is then mapped by a signal point mapping element 666. For the scheme whereby DRC messages are mapped to different points in the signal constellation, signal point mapping element 666 maps the received

codeword to the corresponding point. For other schemes, the codeword may be mapped as described above (e.g., bits in the codeword may be mapped such that "0" → +1, and "1" → -1). The mapped codeword may then be scaled by a gain element 667. As noted above, a codeword with a larger minimum distance may be transmitted with less transmit power, and this codeword would be scaled smaller by gain element 667. Conversely, a codeword with a smaller minimum distance may be scaled larger by gain element 667. Thus, the codeword is scaled by a factor related to the signal quality at which the codeword may be received.

The scaled codeword is then covered by a coverer 668 with a particular 8-ary Walsh function, W_i^8, provided by a Walsh cover generator 670. This Walsh function, W_i^8, is the one assigned to the selected access point having the best link to the access terminal. Each Walsh chip from coverer 668 is further covered by a coverer 672 with a 16-bit Walsh function, W_8^{16} (i.e., a sequence of "1111111100000000") to generate the required number of chips. The sequence of (e.g., 2048) chips for the DRC message is then combined with other data within a combiner, and the combined data is provided to the next processing element (e.g., modulator 644).The processing of the message transmission from the access terminal may be achieved using an architecture similar to that shown in FIG. 6A. Depending on the particular scheme used for the message, the detection of the message may be performed within the demodulator (e.g., demodulator 624) or the receive data processor (e.g., processor 626). If the messages are associated with different points on a signal constellation, the demodulator can compared the received point versus the possible points in the signal constellation and declare the most likely transmitted message based on the comparison of the received and possible points. And if the messages are associated with different codewords (e.g., of different minimum distances or different lengths), the receive data processor can process the received codeword and declare the most likely transmitted message based on the comparison of the received and possible codewords.

For clarity, various aspects, embodiments, and features of the message transmission schemes of the invention have been specifically described for the DRC messages in the HDR system. The message transmission schemes described herein may be used for any set of defined messages to be transmitted on any channel on the forward or reverse link. The message transmission schemes of the invention may also be used for other wireless communication systems and for other CDMA systems that may support one or more other CDMA standards and/or designs.

The foregoing description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

CLAIMS

1. In a wireless communication system, a method for transmitting a control message from a first entity to a second entity, comprising:

at the first entity, measuring at least one characteristic of a channel through which a signal is received from the second entity to produce channel state information;

forming the control message indicative of the channel state information; and

transmitting the control message from the first entity to the second entity at a particular power level determined based at least in part on the control message.

2. The method of claim 1, wherein the control message comprises a particular codeword selected from among a plurality of possible codewords.

3. The method of claim 2, wherein the power level is determined based on a minimum distance of the selected codeword.

4. The method of claim 2, wherein the power level is determined based on an expected frequency of the selected codeword being transmitted.

5. The method of claim 2, wherein the power level is determined based on a particular number of times the selected codeword is repeated for a transmission.

6. The method of claim 1, wherein the control message is a data rate control message indicative of a rate for a data transmission requested from the second entity.

7. The method of claim 1, wherein the at least one characteristic comprises a carrier-to-noise-plus interference ratio (C/I).

8. The method of claim 1, wherein the control message is selected from among a plurality of data rate control messages.

9. The method of claim 2, wherein the selected codeword has a minimum distance based on quality of the channel.

10. The method of claim 2, wherein the selected codeword has a minimum distance based on frequency in which the control message is transmitted.

11. In a wireless communication system, a method for transmitting a message from a first entity to a second entity, comprising:

identifying a codeword associated with the message, wherein the identified codeword is one of a plurality of codewords defined for an alphabet, and wherein at least two codewords in the alphabet have unequal distances to their nearest codewords; and

transmitting the identified codeword from the first entity to the second entity.

12. The method of claim 11, further comprising:

determining a transmit power level for the identified codeword, and

wherein the identified codeword is transmitted at the determined transmit power level.

13. The method of claim 12, wherein the transmit power level for the identified codeword is based at least in part on the distance of the identified codeword to its nearest codeword.

14. The method of claim 12, wherein the transmit power level for the identified codeword is determined to achieve a particular level of performance.

15. The method of claim 14, wherein the particular level of performance is approximately one percent frame error rate or better.

16. The method of claim 11, wherein the message to be transmitted is one of a plurality of possible messages, and wherein the plurality of codewords in the alphabet are assigned to the plurality of possible messages in accordance with a particular assignment scheme.

17. The method of claim 16, wherein the plurality of codewords in the alphabet are assigned to the plurality of possible messages such that messages more likely to be transmitted at higher transmit power levels are assigned with codewords having larger distances to their nearest codewords.

18. The method of claim 16, wherein the plurality of codewords in the alphabet are assigned to the plurality of possible messages such that messages more likely to be transmitted are assigned with codewords having larger distances to their nearest codewords.

19. The method of claim 11, wherein the alphabet includes N codewords having minimum distances of d_1 through d_N, and wherein the minimum distances conform to the following:

$$d_1 \geq d_2 \geq \ldots \geq d_{N-1} \geq d_N \text{ , and}$$

$$d_1 > d_N \text{ .}$$

20. The method of claim 11, wherein the message identifies a particular data rate for a data transmission requested by the first entity from the second entity.

21. The method of claim 11, wherein the first entity is an access terminal in the wireless communication system.

22. The method of claim 11, wherein the wireless communication system is a CDMA system.

23. In a wireless communication system, a method for transmitting a message from a first entity to a second entity, comprising:

identifying a codeword associated with the message, wherein the identified codeword is one of a plurality of codewords defined for an alphabet, and wherein at least two codewords in the alphabet may be transmitted with different amounts of energy for a particular level of performance under similar link condition;

determining a transmit power level for the identified codeword; and

transmitting the identified codeword at the determined transmit power level.

24. The method of claim 23, wherein at least two codewords in the alphabet have unequal distances to their nearest codewords.

25. The method of claim 23, wherein the plurality of codewords in the alphabet are associate with a plurality of points in a signal constellation, and wherein at least two points in the signal constellation have unequal distances to their nearest codewords.

26. The method of claim 25, wherein the plurality of points in the signal constellation are selected from points in signal constellations for quadrature phase shift keying (QPSK), M-ary phase shift keying (M-PSK), M-ary quadrature amplitude modulation (M-QAM), or a combination thereof.

27. The method of claim 23, wherein at least two codewords in the alphabet have unequal lengths.

28. The method of claim 27, further comprising:

encoding the identified codeword in accordance with a particular coding scheme.

29. The method of claim 23, wherein the message to be transmitted is one of a plurality of possible messages, and wherein the plurality of codewords in the alphabet are assigned to the plurality of possible messages such that messages more likely to be transmitted at higher transmit power level are assigned with codewords requiring lower transmit power to achieve the particular level of performance.

30. The method of claim 23, wherein the message to be transmitted is one of a plurality of possible messages, and wherein the plurality of codewords in the alphabet are assigned to the plurality of possible messages such that messages more likely to be transmitted are assigned with codewords requiring less transmit power to achieve the particular level of performance.

31. An access terminal in a wireless communication system, comprising:

a receiver for receiving a signal from an access network and determining at least one characteristic of a forward link channel through which the signal is received;

a data processor configured to form a control message indicative of a state of the forward link channel; and

a transmitter unit configured to transmit the control message at a particular transmit power determined based at least in part on the control message.

32. An access terminal in a wireless communication system, comprising:

a data processor configured to receive and process a codeword for a message, wherein the codeword is one of a plurality of codewords defined for an alphabet, and wherein at least two codewords in the alphabet may be transmitted with different amounts of energy for a particular level of performance under similar link condition; and

a transmitter unit operatively coupled to the data processor and configured to transmit the processed codeword.

33. The access point of claim 32, further comprising:

a controller operatively coupled to the data processor and configured to provide a signal indicative of transmit power level to be used for the processed codeword.

34. The access point of claim 32, further comprising:

a signal quality measurement unit configured to receive samples for a received signal and to determine a received signal quality of signals transmitted from one or more transmitting sources, and

wherein the processed codeword is transmitted at a power level based in part on the received signal quality of a transmitting source to which the processed codeword is transmitted.

35. A communication unit in a wireless communication system, comprising:

a receiver configured to receive a signal from a transmitting source and determine at least one characteristic of a communication link through which the signal is received;

a data processor configured to form a message indicative of a state of the communication link; and

a transmitter unit configured to transmit the message at a particular transmit power determined based at least in part on the message.

36. An access point in a CDMA system comprising the communication unit of claim 35.

37. An apparatus in a wireless communication system, comprising:

means for receiving a signal from a transmitting source and determining at least one characteristic of a communication link through which the signal is received;

means for forming a control message indicative of a state of the communication link; and

means for transmitting the control message at a particular transmit power determined based at least in part on the control message.

38. The apparatus of claim 37, wherein the control message comprises a codeword selected from among a plurality of codewords defined for an alphabet, and wherein at least two codewords in the alphabet may be transmitted with different transmit power for a particular level of performance under similar link condition.

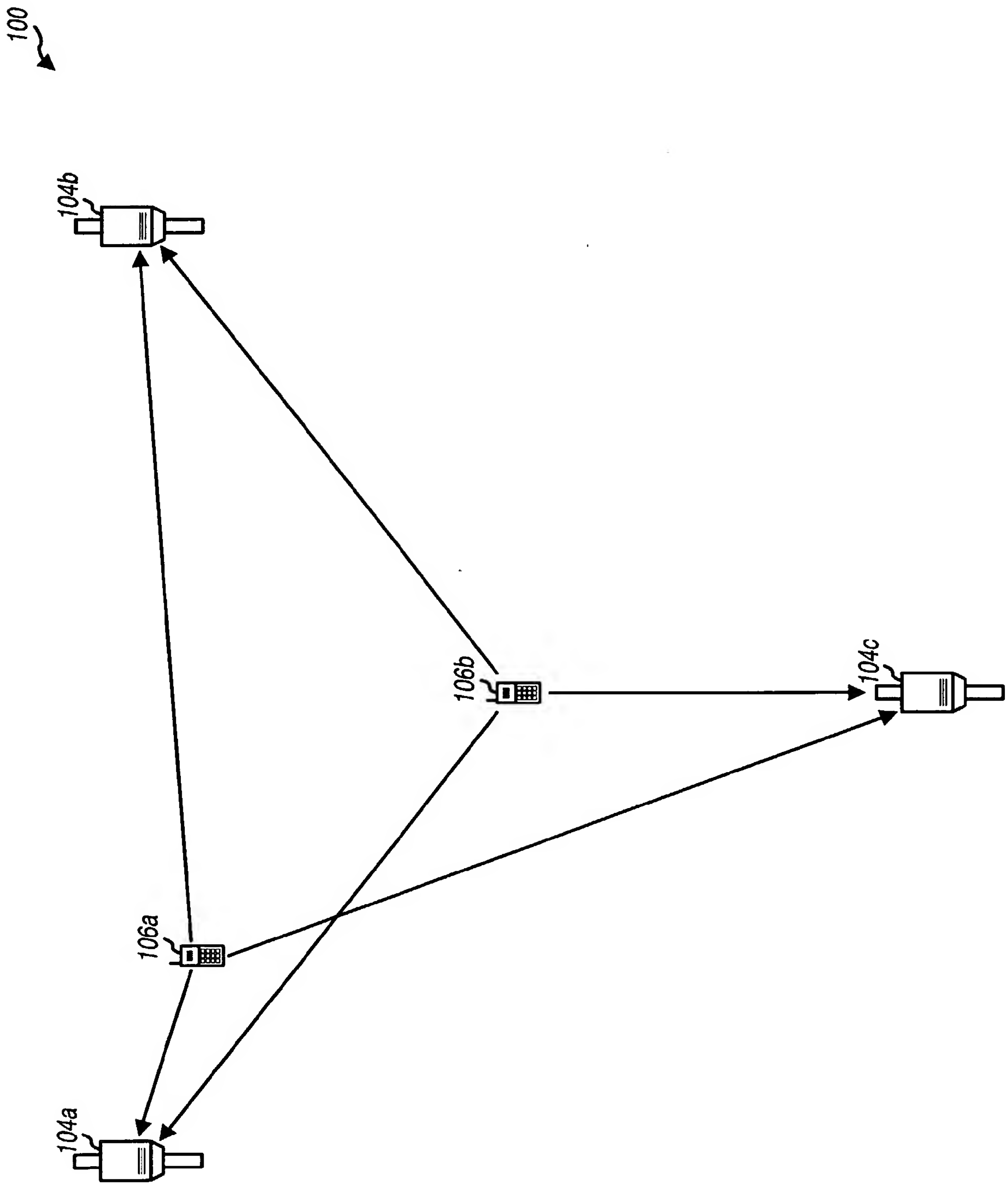


FIG. 1

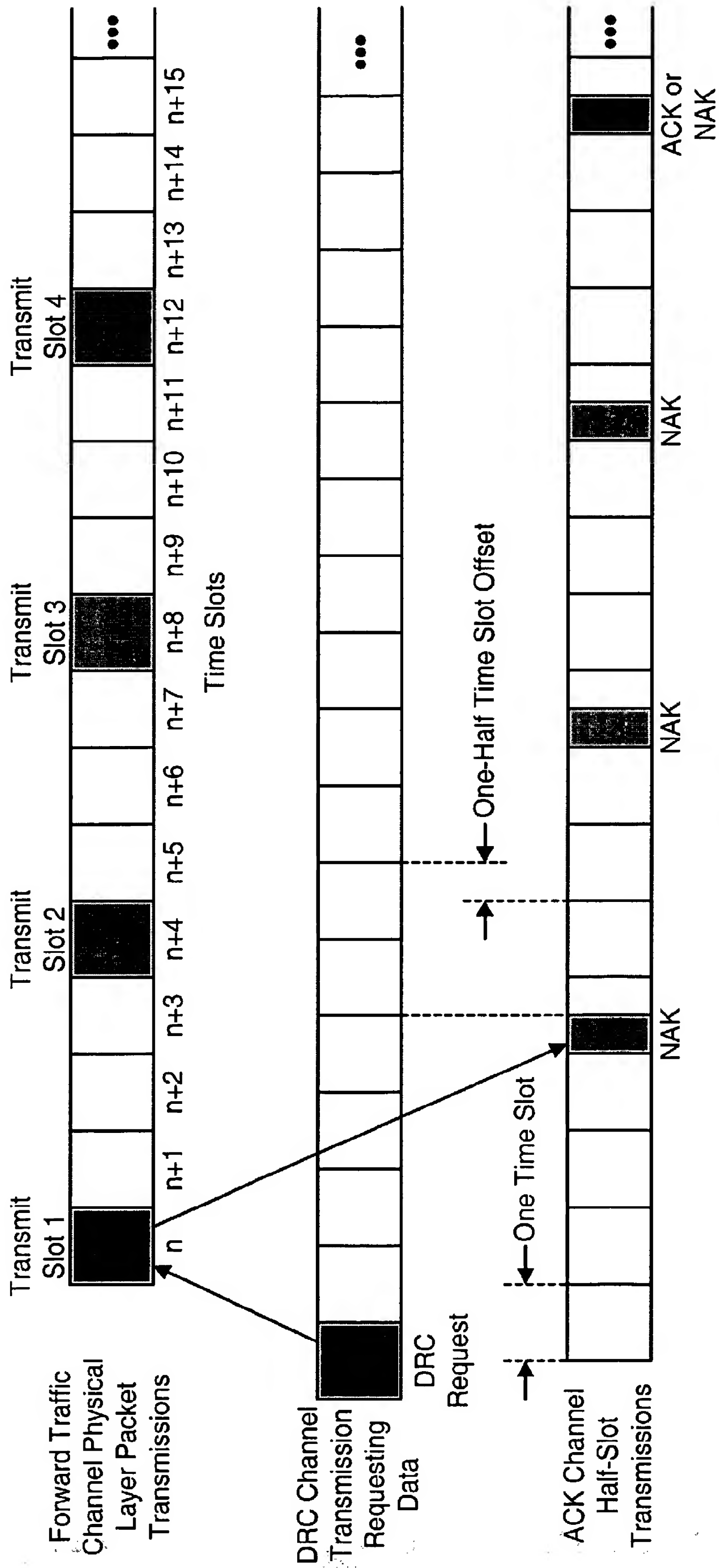

Forward Traffic Channel Physical Layer Packet Transmissions
Transmit Slot 1
Transmit Slot 2
Transmit Slot 3
Transmit Slot 4
n
n+1
n+2
n+3
n+4
n+5
n+6
n+7
n+8
n+9
n+10
n+11
n+12
n+13
n+14
n+15
Time Slots
DRC Channel Transmission Requesting Data
DRC Request
One-Half Time Slot Offset
One Time Slot
ACK Channel Half-Slot Transmissions
NAK
NAK
NAK
ACK or NAK

FIG. 2

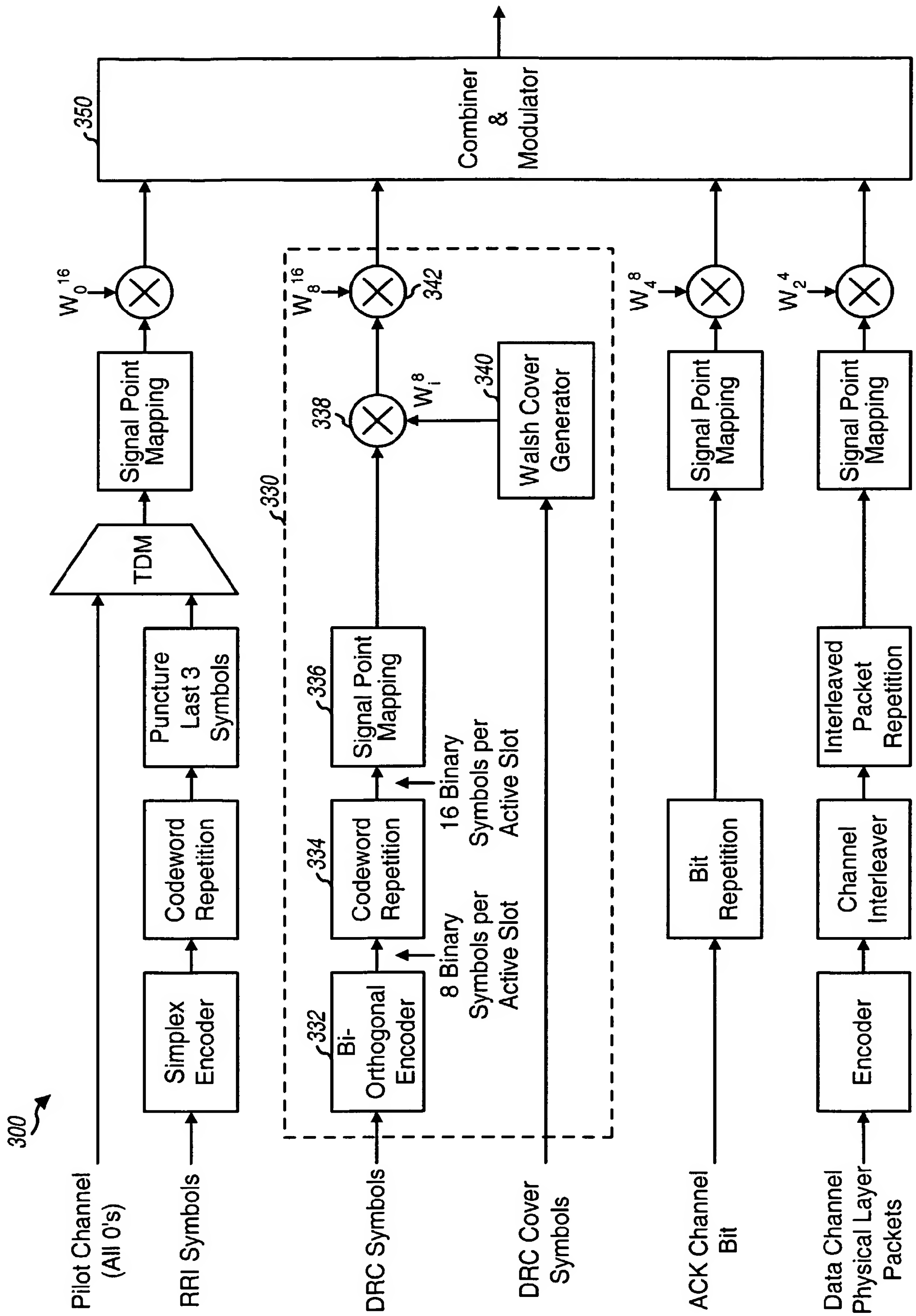

300
Pilot Channel (All 0's)
RRI Symbols
Simplex Encoder
Codeword Repetition
Puncture Last 3 Symbols
TDM
Signal Point Mapping
W_0^{16}
350
Combiner & Modulator
330
DRC Symbols
332
Bi-Orthogonal Encoder
8 Binary Symbols per Active Slot
334
Codeword Repetition
16 Binary Symbols per Active Slot
336
Signal Point Mapping
338
W_i^8
340
Walsh Cover Generator
W_8^{16}
342
DRC Cover Symbols
ACK Channel Bit
Bit Repetition
Signal Point Mapping
W_4^8
Data Channel Physical Layer Packets
Encoder
Channel Interleaver
Interleaved Packet Repetition
Signal Point Mapping
W_2^4

FIG. 3

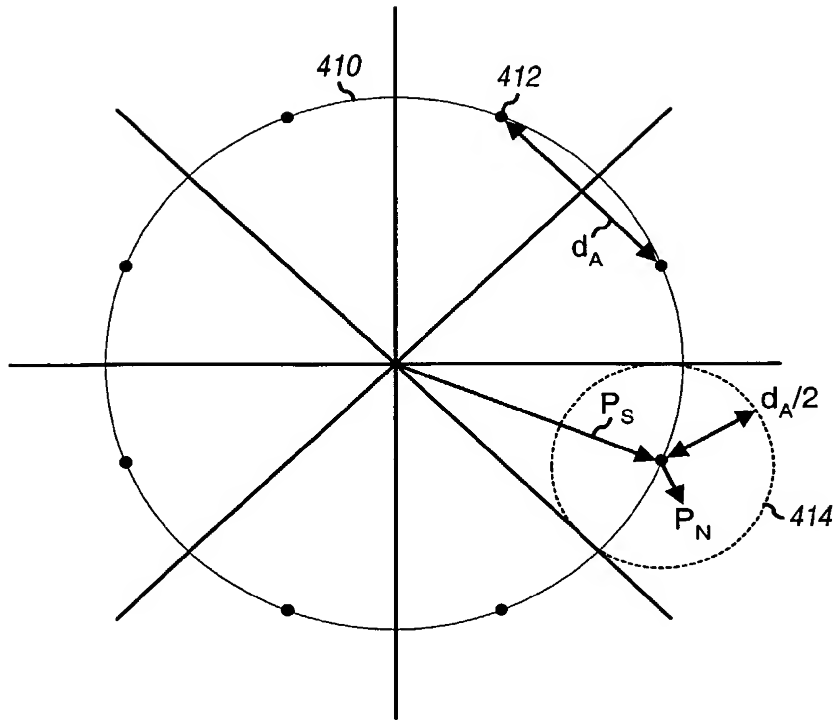

410
412
d_A
P_S
$d_A/2$
P_N
414

FIG. 4A

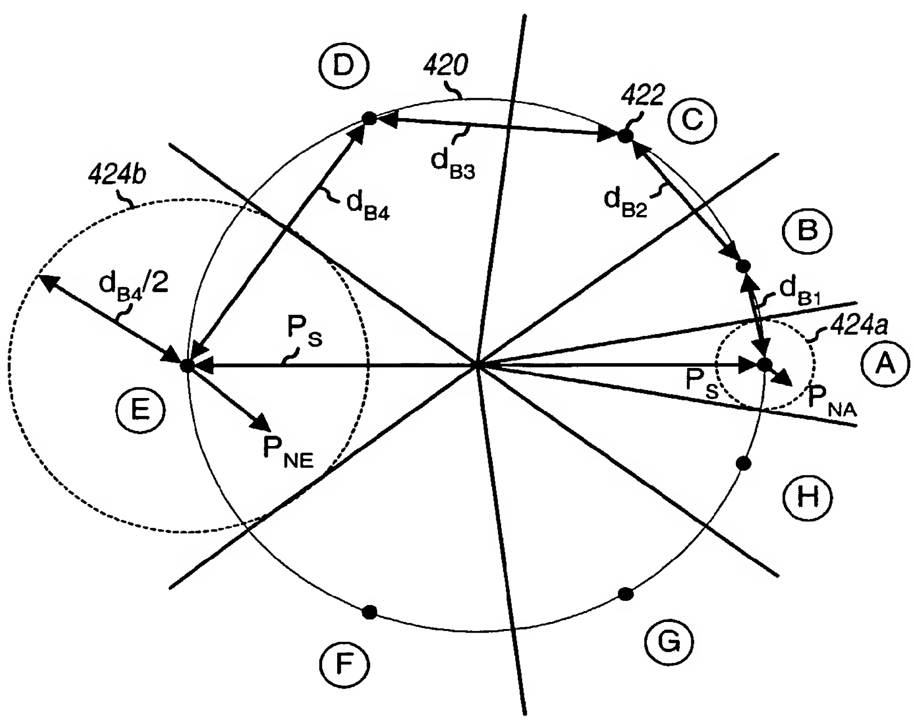
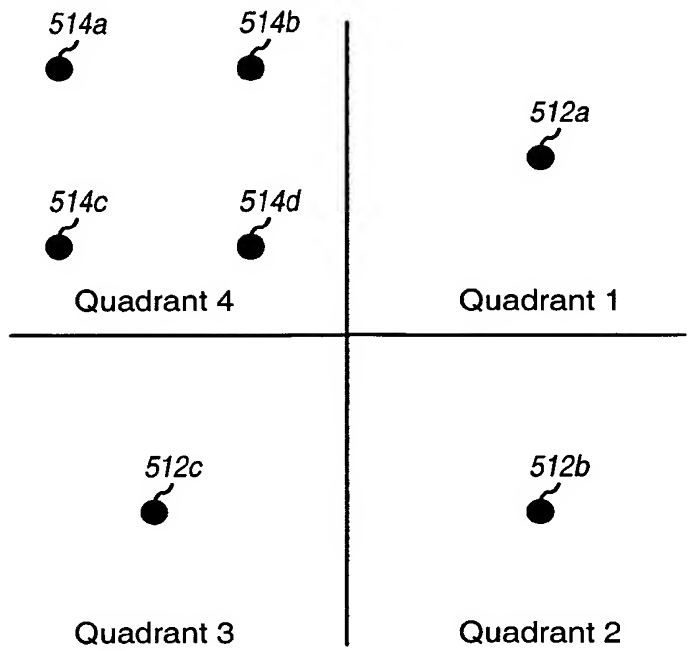

D
420
422
C
d_{B3}
424b
d_{B4}
d_{B2}
B
$d_{B4}/2$
d_{B1}
424a
P_S
A
P_S
P_{NA}
E
P_{NE}
H
G
F

FIG. 4B



514a
514b
512a
514c
514d
Quadrant 4
Quadrant 1
512c
512b
Quadrant 3
Quadrant 2

FIG. 5A

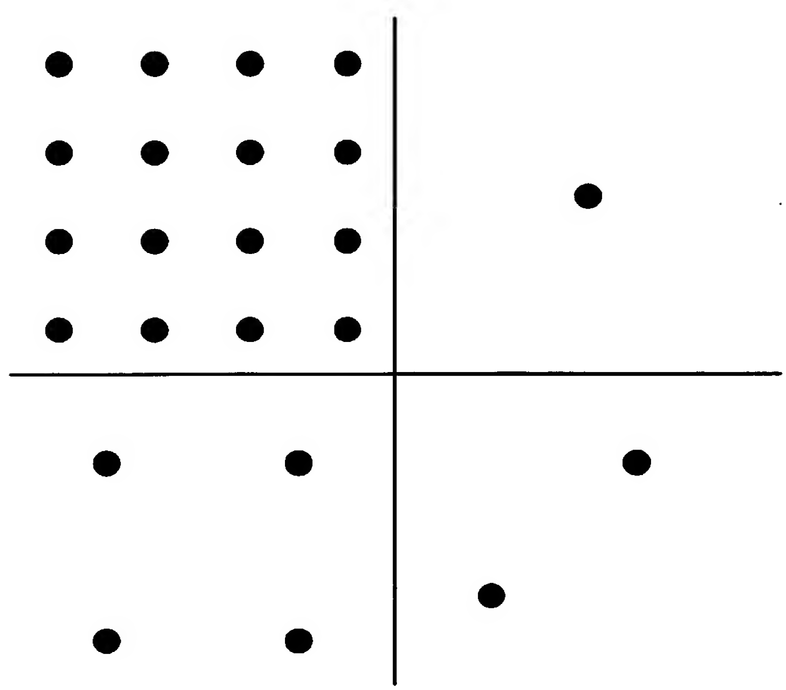


FIG. 5B

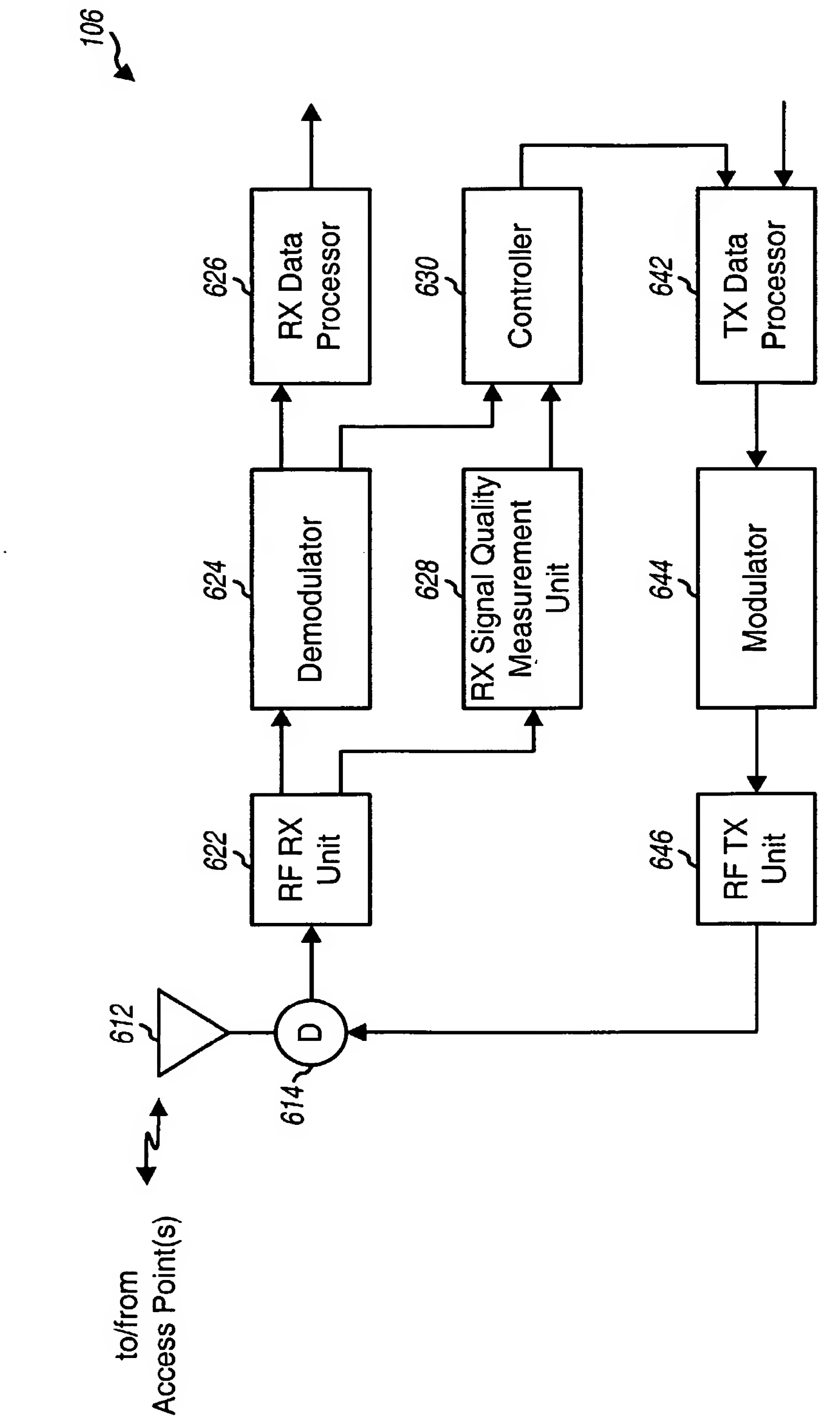

106
to/from
Access Point(s)
612
614
D
622
RF RX
Unit
624
Demodulator
626
RX Data
Processor
628
RX Signal Quality
Measurement
Unit
630
Controller
642
TX Data
Processor
644
Modulator
646
RF TX
Unit

FIG. 6A

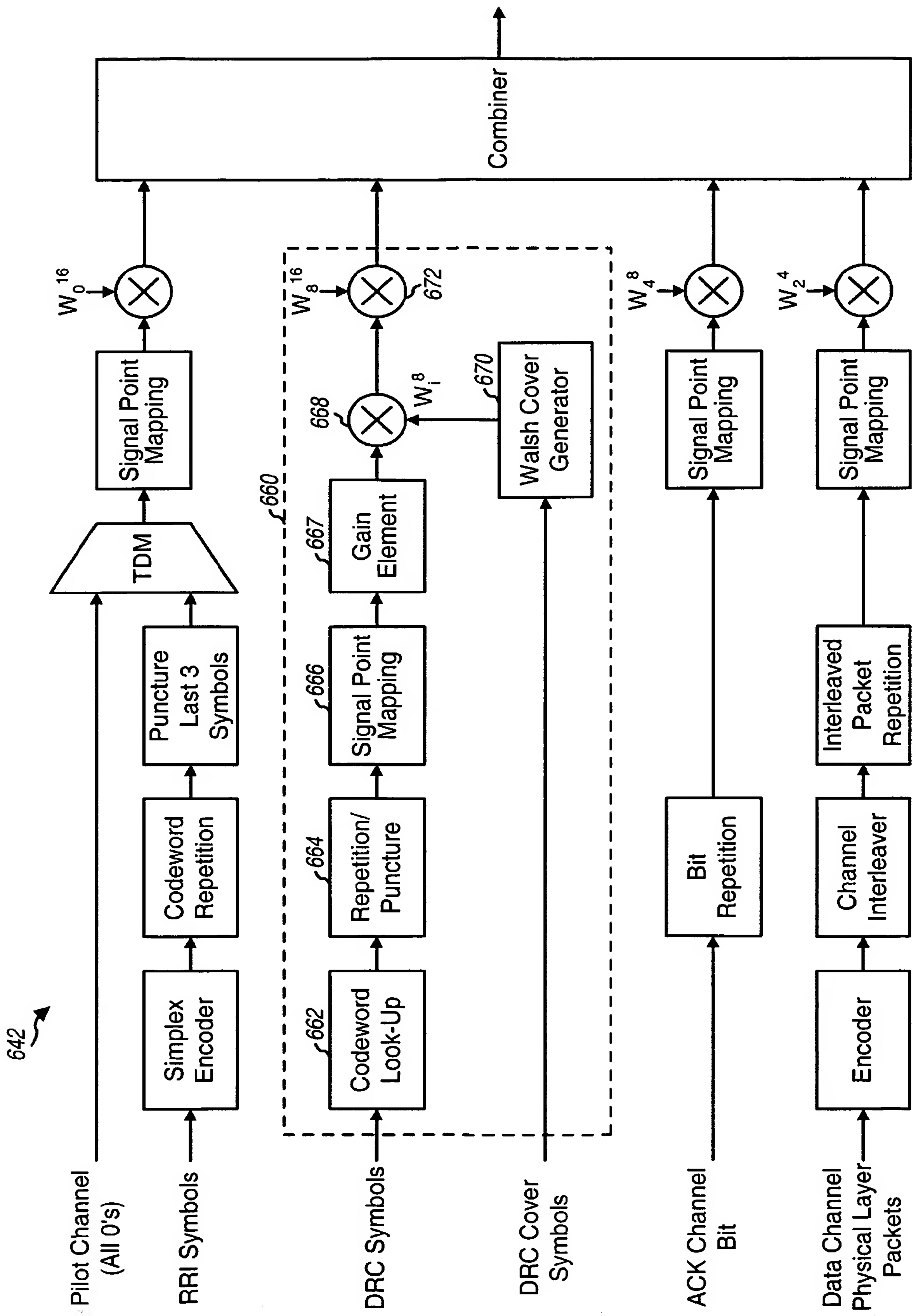

642
Pilot Channel (All 0's)
RRI Symbols
Simplex Encoder
Codeword Repetition
Puncture Last 3 Symbols
TDM
Signal Point Mapping
W_0^{16}
660
DRC Symbols
662
Codeword Look-Up
664
Repetition/ Puncture
666
Signal Point Mapping
667
Gain Element
668
W_i^8
670
Walsh Cover Generator
DRC Cover Symbols
W_8^{16}
672
ACK Channel Bit
Bit Repetition
Signal Point Mapping
W_4^8
Data Channel Physical Layer Packets
Encoder
Channel Interleaver
Interleaved Packet Repetition
Signal Point Mapping
W_2^4
Combiner

FIG. 6B

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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

Published:

— *with international search report*

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(54) Title: COMBINING ACKNOWLEDGEMENT AND RATE CONTROL

(57) Abstract: Embodiments disclosed herein address the need in the art for reduced overhead control with the ability to adjust transmission rates as necessary. In one aspect, a first signal indicates an acknowledgement of a decoded subpacket and whether or not a rate control command is generated, and a second signal conditionally indicates the rate control command when one is generated. In another aspect, a grant may be generated concurrently with the acknowledgement. In yet another aspect, a mobile station monitors the first signal, conditionally monitors the second signal as indicated by the first signal, and may monitor a third signal comprising a grant. In yet another aspect, one or more base stations transmit one or more of the various signals. Various other aspects are also presented. These aspects have the benefit of providing the flexibility of grant-based control while utilizing lower overhead when rate control commands are used, thus increasing system utilization, increasing capacity and throughput.

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

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COMBINING ACKNOWLEDGEMENT AND RATE CONTROL

BACKGROUND

Claim of Priority under 35 U.S.C. §119

[0001] The present Application for Patent claims priority to Provisional Application No. 60/493,046 entitled "Reverse Link Rate Control for CDMA 2000 Rev D" filed August 5, 2003, and Provisional Application No. 60/496,297, entitled "Reverse Link Rate Control for CDMA 2000 Rev D", filed August 18, 2003.

Field

[0002] The present invention relates generally to wireless communications, and more specifically to combining grant, acknowledgement, and rate control channels.

Background

[0003] Wireless communication systems are widely deployed to provide various types of communication such as voice and data. A typical wireless data system, or network, provides multiple users access to one or more shared resources. A system may use a variety of multiple access techniques such as Frequency Division Multiplexing (FDM), Time Division Multiplexing (TDM), Code Division Multiplexing (CDM), and others.

[0004] Example wireless networks include cellular-based data systems. The following are several such examples: (1) the "TIA/EIA-95-B Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" (the IS-95 standard), (2) the standard offered by a consortium named "3rd Generation Partnership Project" (3GPP) and embodied in a set of documents including Document Nos. 3G TS 25.211, 3G TS 25.212, 3G TS 25.213, and 3G TS 25.214 (the W-CDMA standard), (3) the standard offered by a consortium named "3rd Generation Partnership Project 2" (3GPP2) and embodied in "TR-45.5 Physical Layer Standard for cdma2000 Spread Spectrum Systems" (the IS-2000 standard), (4) the high data rate (HDR) system that conforms to the TIA/EIA/IS-856 standard (the IS-856 standard), and (5) Revision C of the IS-2000 standard, including C.S0001.C through C.S0006.C, and related

documents (including subsequent Revision D submissions) are referred to as the 1xEV-DV proposal.

[0005] In an example system, Revision D of the IS-2000 standard (currently under development), the transmission of mobile stations on the reverse link is controlled by the base stations. A base station may decide the maximum rate or Traffic-to-Pilot Ratio (TPR) at which a mobile station is allowed to transmit. Currently proposed are two types of control mechanisms: grant based and rate-control based.

[0006] In grant-based control, a mobile station feeds back to a base station information on the mobile station's transmit capability, data buffer size, and Quality of Service (QoS) level, etc. The base station monitors feedback from a plurality of mobile stations and decides which are allowed to transmit and the corresponding maximum rate allowed for each. These decisions are delivered to the mobile stations via grant messages.

[0007] In rate-control based control, a base station adjusts a mobile station's rate with limited range (i.e. one rate up, no change, or one rate down). The adjustment command is conveyed to the mobile stations using a simple binary rate control bit or multiple-valued indicator.

[0008] Under full buffer conditions, where active mobile stations have large amounts of data, grant based techniques and rate control techniques perform roughly the same. Ignoring overhead issues, the grant method may be better able to control the mobile station in situations with real traffic models. Ignoring overhead issues, the grant method may be better able to control different QoS streams. Two types of rate control may be distinguished, including a dedicated rate control approach, giving every mobile station a single bit, and common rate control, using a single bit per sector. Various hybrids of these two may assign multiple mobile stations to a rate control bit. A common rate control approach may require less overhead. However, it may offer less control over mobile stations when contrasted with a more dedicated control scheme. As the number of mobiles transmitting at any one time decreases, then the common rate control method and the dedicated rate control approach each other.

[0009] Grant based techniques can rapidly change the transmission rate of a mobile station. However, a pure grant based technique may suffer from high overhead if there are continual rate changes. Similarly, a pure rate control technique may suffer from slow ramp-up times and equal or higher overheads during the ramp-up times.

[0010] Neither approach provides both reduced overhead and large or rapid rate adjustments. There is therefore a need in the art for reduced overhead control with the ability to adjust transmission rates as necessary.

SUMMARY

[0011] Embodiments disclosed herein address the need in the art for reduced overhead control with the ability to adjust transmission rates as necessary. In one aspect, a first signal indicates an acknowledgement of a decoded subpacket and whether or not a rate control command is generated, and a second signal conditionally indicates the rate control command when one is generated. In another aspect, a grant may be generated concurrently with the acknowledgement. In yet another aspect, a mobile station monitors the first signal, conditionally monitors the second signal as indicated by the first signal, and may monitor a third signal comprising a grant. In yet another aspect, one or more base stations transmit one or more of the various signals. Various other aspects are also presented. These aspects have the benefit of providing the flexibility of grant-based control while utilizing lower overhead when rate control commands are used, thus increasing system utilization, increasing capacity and throughput.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a general block diagram of a wireless communication system capable of supporting a number of users;

[0013] FIG. 2 depicts an example mobile station and base station configured in a system adapted for data communication;

[0014] FIG. 3 is a block diagram of a wireless communication device, such as a mobile station or base station;

[0015] FIG. 4 depicts an exemplary embodiment of data and control signals for reverse link data communication;

[0016] FIG. 5 is an exemplary acknowledgement channel;

[0017] FIG. 6 is an exemplary rate control channel;

[0018] FIG. 7 is an example method deployable in a base station to allocate capacity in response to requests and transmissions from one or more mobile stations;

[0019] FIG. 8 is an example method of generating grants, acknowledgements, and rate control commands;

[0020] FIG. 9 is an example method for a mobile station to monitor and respond to grants, acknowledgements, and rate control commands;

[0021] FIG. 10 depicts timing for an example embodiment with combined acknowledgement and rate control channels;

[0022] FIG. 11 depicts timing for an example embodiment with combined acknowledgement and rate control channels, along with a new grant; and

[0023] FIG. 12 depicts timing for an example embodiment with combined acknowledgement and rate control channels, without a grant.

DETAILED DESCRIPTION

[0024] Example embodiments, detailed below, provide for allocation of a shared resource, such as shared by one or more mobile stations in a communication system, by advantageously controlling or adjusting one or more data rates in connection with various acknowledgment messages communicated in the system.

[0025] Techniques for combining the use of grant channels, acknowledgement channels, and rate control channels to provide for a combination of grant based scheduling and rate controlled scheduling, and the benefits thereof, are disclosed herein. Various embodiments may allow for one or more of the following benefits: increasing the transmission rate of a mobile station quickly, quickly stopping a mobile station from transmitting, low-overhead adjustments of a mobile station's rate, low-overhead mobile station transmission acknowledgement, low overhead overall, and Quality of Service (QoS) control for streams from one or mobile stations. Various other benefits will be detailed below.

[0026] One or more exemplary embodiments described herein are set forth in the context of a digital wireless data communication system. While use within this context is advantageous, different embodiments of the invention may be incorporated in different environments or configurations. In general, the various systems described herein may be formed using software-controlled processors, integrated circuits, or discrete logic. The data, instructions, commands, information, signals, symbols, and chips that may be referenced throughout the application are advantageously represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or a combination thereof. In addition, the blocks shown in each block diagram may represent hardware or method steps.

[0027] More specifically, various embodiments of the invention may be incorporated in a wireless communication system operating in accordance with a communication standard outlined and disclosed in various standards published by the Telecommunication Industry Association (TIA) and other standards organizations. Such standards include the TIA/EIA-95 standard, TIA/EIA-IS-2000 standard, IMT-2000 standard, UMTS and WCDMA standard, GSM standard, all incorporated by reference herein. A copy of the standards may be obtained by writing to TIA, Standards and Technology Department, 2500 Wilson Boulevard, Arlington, VA 22201, United States of America. The standard generally identified as UMTS standard, incorporated by reference herein, may be obtained by contacting 3GPP Support Office, 650 Route des Lucioles-Sophia Antipolis, Valbonne-France.

[0028] FIG. 1 is a diagram of a wireless communication system 100 that may be designed to support one or more CDMA standards and/or designs (e.g., the W-CDMA standard, the IS-95 standard, the cdma2000 standard, the HDR specification, the 1xEV-DV system). In an alternative embodiment, system 100 may additionally support any wireless standard or design other than a CDMA system. In the exemplary embodiment, system 100 is a 1xEV-DV system.

[0029] For simplicity, system 100 is shown to include three base stations 104 in communication with two mobile stations 106. The base station and its coverage area are often collectively referred to as a "cell". In IS-95, cdma2000, or 1xEV-DV systems, for example, a cell may include one or more sectors. In the W-CDMA specification, each sector of a base station and the sector's coverage area is referred to as a cell. As used herein, the term base station can be used interchangeably with the terms access point or Node B. The term mobile station can be used interchangeably with the terms user equipment (UE), subscriber unit, subscriber station, access terminal, remote terminal, or other corresponding terms known in the art. The term mobile station encompasses fixed wireless applications.

[0030] Depending on the CDMA system being implemented, each mobile station 106 may communicate with one (or possibly more) base stations 104 on the forward link at any given moment, and may communicate with one or more base stations on the reverse link depending on whether or not the mobile station is in soft handoff. The forward link (i.e., downlink) refers to transmission from the base station to the mobile station, and the reverse link (i.e., uplink) refers to transmission from the mobile station to the base station.

[0031] While the various embodiments described herein are directed to providing reverse-link or forward-link signals for supporting reverse link transmission, and some may be well suited to the nature of reverse link transmission, those skilled in the art will understand that mobile stations as well as base stations can be equipped to transmit data as described herein and the aspects of the present invention apply in those situations as well. The word “exemplary” is used exclusively herein to mean “serving as an example, instance, or illustration.” Any embodiment described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments.

1xEV-DV Forward Link Data Transmission

[0032] A system 100, such as the one described in the 1xEV-DV proposal, generally comprises forward link channels of four classes: overhead channels, dynamically varying IS-95 and IS-2000 channels, a Forward Packet Data Channel (F-PDCH), and some spare channels. The overhead channel assignments vary slowly; for example, they may not change for months. They are typically changed when there are major network configuration changes. The dynamically varying IS-95 and IS-2000 channels are allocated on a per call basis or are used for IS-95, or IS-2000 Release 0 through B voice and packet services. Typically, the available base station power remaining after the overhead channels and dynamically varying channels have been assigned is allocated to the F-PDCH for remaining data services

[0033] The F-PDCH, similar to the traffic channel in the IS-856 standard, is used to send data at the highest supportable data rate to one or two users in each cell at a time. In IS-856, the entire power of the base station and the entire space of Walsh functions are available when transmitting data to a mobile station. However, in a 1xEV-DV system, some base station power and some of the Walsh functions are allocated to overhead channels and existing IS-95 and cdma2000 services. The data rate that is supportable depends primarily upon the available power and Walsh codes after the power and Walsh codes for the overhead, IS-95, and IS-2000 channels have been assigned. The data transmitted on the F-PDCH is spread using one or more Walsh codes.

[0034] In a 1xEV-DV system, the base station generally transmits to one mobile station on the F-PDCH at a time, although many users may be using packet services in a cell. (It is also possible to transmit to two users by scheduling transmissions for the two users, and allocating power and Walsh channels to each user appropriately.) Mobile

stations are selected for forward link transmission based upon some scheduling algorithm.

[0035] In a system similar to IS-856 or 1xEV-DV, scheduling is based in part on channel quality feedback from the mobile stations being serviced. For example, in IS-856, mobile stations estimate the quality of the forward link and compute a transmission rate expected to be sustainable for the current conditions. The desired rate from each mobile station is transmitted to the base station. The scheduling algorithm may, for example, select a mobile station for transmission that supports a relatively higher transmission rate in order to make more efficient use of the shared communication channel. As another example, in a 1xEV-DV system, each mobile station transmits a Carrier-to-Interference (C/I) estimate as the channel quality estimate on the Reverse Channel Quality Indicator Channel (R-CQICH). The scheduling algorithm is used to determine the mobile station selected for transmission, as well as the appropriate rate and transmission format in accordance with the channel quality.

[0036] As described above, a wireless communication system 100 may support multiple users sharing the communication resource simultaneously, such as an IS-95 system, may allocate the entire communication resource to one user at time, such as an IS-856 system, or may apportion the communication resource to allow both types of access. A 1xEV-DV system is an example of a system that divides the communication resource between both types of access, and dynamically allocates the apportionment according to user demand. An exemplary forward-link embodiment has just been described. Various exemplary reverse-link embodiments are detailed further below.

[0037] FIG. 2 depicts an example mobile station 106 and base station 104 configured in a system 100 adapted for data communication. Base station 104 and mobile station 106 are shown communicating on a forward and a reverse link. Mobile station 106 receives forward link signals in receiving subsystem 220. A base station 104 communicating the forward data and control channels, detailed below, may be referred to herein as the serving station for the mobile station 106. An example receiving subsystem is detailed further below with respect to FIG. 3. A Carrier-to-Interference (C/I) estimate is made for the forward link signal received from the serving base station in the mobile station 106. A C/I measurement is an example of a channel quality metric used as a channel estimate, and alternate channel quality metrics can be deployed in alternate embodiments. The C/I measurement is delivered to transmission subsystem 210 in the base station 104, an example of which is detailed further below with respect to FIG. 3.

[0038] The transmission subsystem 210 delivers the C/I estimate over the reverse link where it is delivered to the serving base station. Note that, in a soft handoff situation, well known in the art, the reverse link signals transmitted from a mobile station may be received by one or more base stations other than the serving base station, referred to herein as non-serving base stations. Receiving subsystem 230, in base station 104, receives the C/I information from mobile station 106.

[0039] Scheduler 240, in base station 104, is used to determine whether and how data should be transmitted to one or more mobile stations within the serving cell's coverage area. Any type of scheduling algorithm can be deployed within the scope of the present invention. One example is disclosed in U.S. Patent Application No. 08/798,951, entitled "METHOD AND APPARATUS FOR FORWARD LINK RATE SCHEDULING", filed February 11, 1997, assigned to the assignee of the present invention.

[0040] In an example 1xEV-DV embodiment, a mobile station is selected for forward link transmission when the C/I measurement received from that mobile station indicates that data can be transmitted at a certain rate. It is advantageous, in terms of system capacity, to select a target mobile station such that the shared communication resource is always utilized at its maximum supportable rate. Thus, the typical target mobile station selected may be the one with the greatest reported C/I. Other factors may also be incorporated in a scheduling decision. For example, minimum quality of service guarantees may have been made to various users. It may be that a mobile station, with a relatively lower reported C/I, is selected for transmission to maintain a minimum data transfer rate to that user. It may be that a mobile station, not with the greatest reported C/I, is selected for transmission to maintain certain fairness criterion among all users.

[0041] In the example 1xEV-DV system, scheduler 240 determines which mobile station to transmit to, and also the data rate, modulation format, and power level for that transmission. In an alternate embodiment, such as an IS-856 system, for example, a supportable rate/modulation format decision can be made at the mobile station, based on channel quality measured at the mobile station, and the transmit format can be transmitted to the serving base station in lieu of the C/I measurement. Those of skill in the art will recognize myriad combinations of supportable rates, modulation formats, power levels, and the like which can be deployed within the scope of the present invention. Furthermore, although in various embodiments described herein the

scheduling tasks are performed in the base station, in alternate embodiments, some or all of the scheduling process may take place in the mobile station.

[0042] Scheduler 240 directs transmission subsystem 250 to transmit to the selected mobile station on the forward link using the selected rate, modulation format, power level, and the like.

[0043] In the example embodiment, messages on the control channel, or F-PDCCH, are transmitted along with data on the data channel, or F-PDCH. The control channel can be used to identify the recipient mobile station of the data on the F-PDCH, as well as identifying other communication parameters useful during the communication session. A mobile station should receive and demodulate data from the F-PDCH when the F-PDCCH indicates that mobile station is the target of the transmission. The mobile station responds on the reverse link following the receipt of such data with a message indicating the success or failure of the transmission. Retransmission techniques, well known in the art, are commonly deployed in data communication systems.

[0044] A mobile station may be in communication with more than one base station, a condition known as soft handoff. Soft handoff may include multiple sectors from one base station (or one Base Transceiver Subsystem (BTS)), known as softer handoff, as well as with sectors from multiple BTSs. Base station sectors in soft handoff are generally stored in a mobile station's Active Set. In a simultaneously shared communication resource system, such as IS-95, IS-2000, or the corresponding portion of a 1xEV-DV system, the mobile station may combine forward link signals transmitted from all the sectors in the Active Set. In a data-only system, such as IS-856, or the corresponding portion of a 1xEV-DV system, a mobile station receives a forward link data signal from one base station in the Active Set, the serving base station (determined according to a mobile station selection algorithm, such as those described in the C.S0002.C standard). Other forward link signals, examples of which are detailed further below, may also be received from non-serving base stations.

[0045] Reverse link signals from the mobile station may be received at multiple base stations, and the quality of the reverse link is generally maintained for the base stations in the active set. It is possible for reverse link signals received at multiple base stations to be combined. In general, soft combining reverse link signals from disparately located base stations would require significant network communication bandwidth with very little delay, and so the example systems listed above do not support it. In softer handoff, reverse link signals received at multiple sectors in a single BTS can be

combined without network signaling. While any type of reverse link signal combining may be deployed within the scope of the present invention, in the example systems described above, reverse link power control maintains quality such that reverse link frames are successfully decoded at one BTS (switching diversity).

[0046] Reverse link data transmission may be carried out in system 100 as well. The receiving and transmission subsystems 210 – 230, and 250, described may be deployed to send control signals on the forward link to direct data transmission on the reverse link. Mobile stations 106 may transmit control information on the reverse link as well. Various mobile stations 106 communicating with one or more base stations 104 may access the shared communication resource (i.e. the reverse link channel, which may be variably allocated, as in 1xEV-DV, or a fixed allocation, as in IS-856), in response to various access control and rate control techniques, examples of which are detailed below. Scheduler 240 may be deployed to determine the allocation of reverse link resources. Example control and data signals for reverse link data communication are detailed below.

Example Base Station and Mobile Station Embodiments

[0047] FIG. 3 is a block diagram of a wireless communication device, such as mobile station 106 or base station 104. The blocks depicted in this example embodiment will generally be a subset of the components included in either a base station 104 or mobile station 106. Those of skill in the art will readily adapt the embodiment shown in FIG. 3 for use in any number of base station or mobile station configurations.

[0048] Signals are received at antenna 310 and delivered to receiver 320. Receiver 320 performs processing according to one or more wireless system standards, such as the standards listed above. Receiver 320 performs various processing such as Radio Frequency (RF) to baseband conversion, amplification, analog to digital conversion, filtering, and the like. Various techniques for receiving are known in the art. Receiver 320 may be used to measure channel quality of the forward or reverse link, when the device is a mobile station or base station, respectively, although a separate channel quality estimator 335 is shown for clarity of discussion, detailed below.

[0049] Signals from receiver 320 are demodulated in demodulator 325 according to one or more communication standards. In an example embodiment, a demodulator capable of demodulating 1xEV-DV signals is deployed. In alternate embodiments, alternate standards may be supported, and embodiments may support multiple communication

formats. Demodulator 330 may perform RAKE receiving, equalization, combining, deinterleaving, decoding, and various other functions as required by the format of the received signals. Various demodulation techniques are known in the art. In a base station 104, demodulator 325 will demodulate according to the reverse link. In a mobile station 106, demodulator 325 will demodulate according to the forward link. Both the data and control channels described herein are examples of channels that can be received and demodulated in receiver 320 and demodulator 325. Demodulation of the forward data channel will occur in accordance with signaling on the control channel, as described above.

[0050] Message decoder 330 receives demodulated data and extracts signals or messages directed to the mobile station 106 or base station 104 on the forward or reverse links, respectively. Message decoder 330 decodes various messages used in setting up, maintaining and tearing down a call (including voice or data sessions) on a system. Messages may include channel quality indications, such as C/I measurements, power control messages, or control channel messages used for demodulating the forward data channel. Various types of control messages may be decoded in either a base station 104 or mobile station 106 as transmitted on the reverse or forward links, respectively. For example, described below are request messages and grant messages for scheduling reverse link data transmission for generation in a mobile station or base station, respectively. Various other message types are known in the art and may be specified in the various communication standards being supported. The messages are delivered to processor 350 for use in subsequent processing. Some or all of the functions of message decoder 330 may be carried out in processor 350, although a discrete block is shown for clarity of discussion. Alternatively, demodulator 325 may decode certain information and send it directly to processor 350 (a single bit message such as an ACK/NAK or a power control up/down command are examples). Various signals and messages for use in embodiments disclosed herein are detailed further below.

[0051] Channel quality estimator 335 is connected to receiver 320, and used for making various power level estimates for use in procedures described herein, as well as for use in various other processing used in communication, such as demodulation. In a mobile station 106, C/I measurements may be made. In addition, measurements of any signal or channel used in the system may be measured in the channel quality estimator 335 of a given embodiment. In a base station 104 or mobile station 106, signal strength

estimations, such as received pilot power can be made. Channel quality estimator 335 is shown as a discrete block for clarity of discussion only. It is common for such a block to be incorporated within another block, such as receiver 320 or demodulator 325. Various types of signal strength estimates can be made, depending on which signal or which system type is being estimated. In general, any type of channel quality metric estimation block can be deployed in place of channel quality estimator 335 within the scope of the present invention. In a base station 104, the channel quality estimates are delivered to processor 350 for use in scheduling, or determining the reverse link quality, as described further below. Channel quality estimates may be used to determine whether up or down power control commands are required to drive either the forward or reverse link power to a desired set point. The desired set point may be determined with an outer loop power control mechanism.

[0052] Signals are transmitted via antenna 310. Transmitted signals are formatted in transmitter 370 according to one or more wireless system standards, such as those listed above. Examples of components that may be included in transmitter 370 are amplifiers, filters, digital-to-analog (D/A) converters, radio frequency (RF) converters, and the like. Data for transmission is provided to transmitter 370 by modulator 365. Data and control channels can be formatted for transmission in accordance with a variety of formats. Data for transmission on the forward link data channel may be formatted in modulator 365 according to a rate and modulation format indicated by a scheduling algorithm in accordance with a C/I or other channel quality measurement. A scheduler, such as scheduler 240, described above, may reside in processor 350. Similarly, transmitter 370 may be directed to transmit at a power level in accordance with the scheduling algorithm. Examples of components, which may be incorporated in modulator 365, include encoders, interleavers, spreaders, and modulators of various types. A reverse link design, including example modulation formats and access control, suitable for deployment on a 1xEV-DV system is also described below.

[0053] Message generator 360 may be used to prepare messages of various types, as described herein. For example, C/I messages may be generated in a mobile station for transmission on the reverse link. Various types of control messages may be generated in either a base station 104 or mobile station 106 for transmission on the forward or reverse links, respectively. For example, described below are request messages and grant messages for scheduling reverse link data transmission for generation in a mobile station or base station, respectively.

[0054] Data received and demodulated in demodulator 325 may be delivered to processor 350 for use in voice or data communications, as well as to various other components. Similarly data for transmission may be directed to modulator 365 and transmitter 370 from processor 350. For example, various data applications may be present on processor 350, or on another processor included in the wireless communication device 104 or 106 (not shown). A base station 104 may be connected, via other equipment not shown, to one or more external networks, such as the Internet (not shown). A mobile station 106 may include a link to an external device, such as a laptop computer (not shown).

[0055] Processor 350 may be a general-purpose microprocessor, a digital signal processor (DSP), or a special-purpose processor. Processor 350 may perform some or all of the functions of receiver 320, demodulator 325, message decoder 330, channel quality estimator 335, message generator 360, modulator 365, or transmitter 370, as well as any other processing required by the wireless communication device. Processor 350 may be connected with special-purpose hardware to assist in these tasks (details not shown). Data or voice applications may be external, such as an externally connected laptop computer or connection to a network, may run on an additional processor within wireless communication device 104 or 106 (not shown), or may run on processor 350 itself. Processor 350 is connected with memory 355, which can be used for storing data as well as instructions for performing the various procedures and methods described herein. Those of skill in the art will recognize that memory 355 may be comprised of one or more memory components of various types, that may be embedded in whole or in part within processor 350.

[0056] A typical data communication system may include one or more channels of various types. More specifically, one or more data channels are commonly deployed. It is also common for one or more control channels to be deployed, although in-band control signaling can be included on a data channel. For example, in a 1xEV-DV system, a Forward Packet Data Control Channel (F-PDCCH) and a Forward Packet Data Channel (F-PDCH) are defined for transmission of control and data, respectively, on the forward link. Various example channels for reverse link data transmission are detailed as follows.

<u>1xEV-DV Reverse Link Design Considerations</u>

[0057] In this section, various factors considered in the design of an example embodiment of a reverse link of a wireless communication system are described. In many of the embodiments, detailed further in following sections, signals, parameters, and procedures associated with the 1xEV-DV standard are used. This standard is described for illustrative purposes only, as each of the aspects described herein, and combinations thereof, may be applied to any number of communication systems within the scope of the present invention. This section serves as a partial summary of various aspects of the invention, although it is not exhaustive. Example embodiments are detailed further in subsequent sections below, in which additional aspects are described.

[0058] In many cases, reverse link capacity is interference limited. Base stations allocate available reverse link communication resources to mobile stations for efficient utilization to maximize throughput in accordance with Quality of Service (QoS) requirements for the various mobile stations.

[0059] Maximizing the use of the reverse link communication resource involves several factors. One factor to consider is the mix of scheduled reverse link transmissions from various mobile stations, each of which may be experiencing varying channel quality at any given time. To increase overall throughput (the aggregate data transmitted by all the mobile stations in the cell), it is desirable for the entire reverse link to be fully utilized whenever there is reverse link data to be sent. To fill the available capacity, mobile stations may be granted access at the highest rate they can support, and additional mobile stations may be granted access until capacity is reached. One factor a base station may consider in deciding which mobile stations to schedule is the maximum rate each mobile can support and the amount of data each mobile station has to send. A mobile station capable of higher throughput may be selected instead of an alternate mobile station whose channel does not support the higher throughput.

[0060] Another factor to be considered is the quality of service required by each mobile station. While it may be permissible to delay access to one mobile station in hopes that the channel will improve, opting instead to select a better situated mobile station, it may be that suboptimal mobile stations may need to be granted access to meet minimum quality of service guarantees. Thus, the data throughput scheduled may not be the absolute maximum, but rather maximized considering channel conditions, available mobile station transmit power, and service requirements. It is desirable for any configuration to reduce the signal to noise ratio for the selected mix.

[0061] Various scheduling mechanisms are described below for allowing a mobile station to transmit data on the reverse link. One class of reverse link transmission involves the mobile station making a request to transmit on the reverse link. The base station makes a determination of whether resources are available to accommodate the request. A grant can be made to allow the transmission. This handshake between the mobile station and the base station introduces a delay before the reverse link data can be transmitted. For certain classes of reverse link data, the delay may be acceptable. Other classes may be more delay-sensitive, and alternate techniques for reverse link transmission are detailed below to mitigate delay.

[0062] In addition, reverse link resources are expended to make a request for transmission, and forward link resources are expended to respond to the request, i.e. transmit a grant. When a mobile station's channel quality is low, i.e. low geometry or deep fading, the power required on the forward link to reach the mobile may be relatively high. Various techniques are detailed below to reduce the number or required transmit power of requests and grants required for reverse link data transmission.

[0063] To avoid the delay introduced by a request/grant handshake, as well as to conserve the forward and reverse link resources required to support them, an autonomous reverse link transmission mode is supported. A mobile station may transmit data at a limited rate on the reverse link without making a request or waiting for a grant.

[0064] It may also be desirable to modify the transmission rate of a mobile station that is transmitting in accordance with a grant, or autonomously, without the overhead of a grant. To accomplish this, rate control commands may be implemented along with autonomous and request/grant based scheduling. For example, a set of commands may include a command to increase, decrease and hold steady the current rate of transmission. Such rate control commands may be addressable to each mobile station individually, or to groups of mobile stations. Various example rate control commands, channels, and signals are detailed further below.

[0065] The base station allocates a portion of the reverse link capacity to one or more mobile stations. A mobile station that is granted access is afforded a maximum power level. In the example embodiments described herein, the reverse link resource is allocated using a Traffic to Pilot (T/P) ratio. Since the pilot signal of each mobile station is adaptively controlled via power control, specifying the T/P ratio indicates the available power for use in transmitting data on the reverse link. The base station may

make specific grants to one or more mobile stations, indicating a T/P value specific to each mobile station. The base station may also make a common grant to the remaining mobile stations, which have requested access, indicating a maximum T/P value that is allowed for those remaining mobile stations to transmit. Autonomous and scheduled transmission, individual and common grants, and rate control are detailed further below.

[0066] Various scheduling algorithms are known in the art, and more are yet to be developed, which can be used to determine the various specific and common T/P values for grants as well as desired rate control commands in accordance with the number of registered mobile stations, the probability of autonomous transmission by the mobile stations, the number and size of the outstanding requests, expected average response to grants, and any number of other factors. In one example, a selection is made based on Quality of Service (QoS) priority, efficiency, and the achievable throughput from the set of requesting mobile stations. One example scheduling technique is disclosed in co-pending US Patent Application No. 10/651,810, entitled "SYSTEM AND METHOD FOR A TIME-SCALABLE PRIORITY-BASED SCHEDULER", filed August 28, 2003, assigned to the assignee of the present invention. Additional references include US Patent 5,914,950, entitled "METHOD AND APPARATUS FOR REVERSE LINK RATE SCHEDULING", and US Patent 5,923,650, also entitled "METHOD AND APPARATUS FOR REVERSE LINK RATE SCHEDULING", both assigned to the assignee of the present invention.

[0067] A mobile station may transmit a packet of data using one or more subpackets, where each subpacket contains the complete packet information (each subpacket is not necessarily encoded identically, as various encoding or redundancy may be deployed throughout various subpackets). Retransmission techniques may be deployed to ensure reliable transmission, for example Automatic Repeat reQuest (ARQ). Thus, if the first subpacket is received without error (using a CRC, for example), a positive Acknowledgement (ACK) is sent to the mobile station and no additional subpackets will be sent (recall that each subpacket comprises the entire packet information, in one form or another). If the first subpacket is not received correctly, then a Negative Acknowledgement signal (NAK) is sent to the mobile station, and the second subpacket will be transmitted. The base station can combine the energy of the two subpackets and attempt to decode. The process may be repeated indefinitely, although it is common to specify a maximum number of subpackets. In example embodiments described herein, up to four subpackets may be transmitted. Thus, the probability of correct reception

increases as additional subpackets are received. Detailed below are various ways to combine ARQ responses, rate control commands, and grants, to provide the desired level of flexibility in transmission rates with acceptable overhead levels.

[0068] As just described, a mobile station may trade off throughput for latency in deciding whether to use autonomous transfer to transmit data with low latency or requesting a higher rate transfer and waiting for a common or specific grant. In addition, for a given T/P, the mobile station may select a data rate to suit latency or throughput. For example, a mobile station with relatively few bits for transmission may decide that low latency is desirable. For the available T/P (probably the autonomous transmission maximum in this example, but could also be the specific or common grant T/P), the mobile station may select a rate and modulation format such that the probability of the base station correctly receiving the first subpacket is high. Although retransmission will be available if necessary, it is likely that this mobile station will be able to transmit its data bits in one subpacket. In various example embodiments described herein, each subpacket is transmitted over a period of 5 ms. Therefore, in this example, a mobile station may make an immediate autonomous transfer that is likely to be received at the base station following a 5 ms interval. Note that, alternatively, the mobile station may use the availability of additional subpackets to increase the amount of data transmitted for a given T/P. So, a mobile station may select autonomous transfer to reduce latency associated with requests and grants, and may additionally trade the throughput for a particular T/P to minimize the number of subpackets (hence latency) required. Even if the full number of subpackets is selected, autonomous transfer will be lower latency than request and grant for relatively small data transfers. Those of skill in the art will recognize that as the amount of data to be transmitted grows, requiring multiple packets for transmission, the overall latency may be reduced by switching to a request and grant format, since the penalty of the request and grant will eventually be offset by the increased throughput of a higher data rate across multiple packets. This process is detailed further below, with an example set of transmission rates and formats that can be associated with various T/P assignments.

Reverse Link Data Transmission

[0069] One goal of a reverse link design may be to maintain the Rise-over-Thermal (RoT) at the base station relatively constant as long as there is reverse link data to be

transmitted. Transmission on the reverse link data channel is handled in three different modes:

[0070] Autonomous Transmission: This case is used for traffic requiring low delay. The mobile station is allowed to transmit immediately, up to a certain transmission rate, determined by the serving base station (i.e. the base station to which the mobile station directs its Channel Quality Indicator (CQI)). A serving base station is also referred to as a scheduling base station or a granting base station. The maximum allowed transmission rate for autonomous transmission may be signaled by the serving base station dynamically based on system load, congestion, etc.

[0071] Scheduled Transmission: The mobile station sends an estimate of its buffer size, available power, and possibly other parameters. The base station determines when the mobile station is allowed to transmit. The goal of a scheduler is to limit the number of simultaneous transmissions, thus reducing the interference between mobile stations. The scheduler may attempt to have mobile stations in regions between cells transmit at lower rates so as to reduce interference to neighboring cells, and to tightly control RoT to protect the voice quality on the R-FCH, the DV feedback on R-CQICH and the acknowledgments (R-ACKCH), as well as the stability of the system.

[0072] Rate Controlled Transmission: Whether a mobile station transmits scheduled (i.e. granted) or autonomously, a base station may adjust the transmission rate via rate control commands. Example rate control commands include increasing, decreasing, or holding the current rate. Additional commands may be included to specify how a rate change is to be implemented (i.e. amount of increase or decrease). Rate control commands may be probabilistic or deterministic.

[0073] Various embodiments, detailed herein, contain one or more features designed to improve throughput, capacity, and overall system performance of the reverse link of a wireless communication system. For illustrative purposes only, the data portion of a 1xEV-DV system, in particular, optimization of transmission by various mobile stations on the Enhanced Reverse Supplemental Channel (R-ESCH), is described. Various forward and reverse link channels used in one or more of the example embodiments are detailed in this section. These channels are generally a subset of the channels used in a communication system.

[0074] FIG. 4 depicts an exemplary embodiment of data and control signals for reverse link data communication. A mobile station 106 is shown communicating over various channels, each channel connected to one or more base stations 104A – 104C. Base

station 104A is labeled as the scheduling base station. The other base stations 104B and 104C are part of the Active Set of mobile station 106. There are four types of reverse link signals and four types of forward link signals shown. They are described below.

R-REQCH

[0075] The Reverse Request Channel (R-REQCH) is used by the mobile station to request from the scheduling base station a reverse link transmission of data. In the example embodiment, requests are for transmission on the R-ESCH (detailed further below). In the example embodiment, a request on the R-REQCH includes the T/P ratio the mobile station can support, variable according to changing channel conditions, and the buffer size (i.e. the amount of data awaiting transmission). The request may also specify the Quality of Service (QoS) for the data awaiting transmission. Note that a mobile station may have a single QoS level specified for the mobile station, or, alternately, different QoS levels for different types of service options. Higher layer protocols may indicate the QoS, or other desired parameters (such as latency or throughput requirements) for various data services. In an alternative embodiment, a Reverse Dedicated Control Channel (R-DCCH), used in conjunction with other reverse link signals, such as the Reverse Fundamental Channel (R-FCH) (used for voice services, for example), may be used to carry access requests. In general, access requests may be described as comprising a logical channel, i.e. a Reverse Schedule Request Channel (R-SRCH), which may be mapped onto any existing physical channel, such as the R-DCCH. The example embodiment is backward compatible with existing CDMA systems such as IS-2000 Revision C, and the R-REQCH is a physical channel that can be deployed in the absence of either the R-FCH or the R-DCCH. For clarity, the term R-REQCH is used to describe the access request channel in embodiment descriptions herein, although those of skill in the art will readily extend the principles to any type of access request system, whether the access request channel is logical or physical. The R-REQCH may be gated off until a request is needed, thus reducing interference and conserving system capacity.

[0076] In the example embodiment, the R-REQCH has 12 input bits that consist of the following: 4 bits to specify the maximum R-ESCH T/P ratio that the mobile can support, 4 bits to specify the amount of data in the mobile's buffer, and 4 bits to specify the QoS. Those of skill in the art will recognize that any number of bits and various other fields may be included in alternate embodiments.

F-GCH

[0077] The Forward Grant Channel (F-GCH) is transmitted from the scheduling base station to the mobile station. The F-GCH may be comprised of multiple channels. In the example embodiment, a common F-GCH channel is deployed for making common grants, and one or more individual F-GCH channels are deployed for making individual grants. Grants are made by the scheduling base station in response to one or more requests from one or more mobile stations on their respective R-REQCHs. Grant channels may be labeled as GCH_x, where the subscript x identifies the channel number. A channel number 0 may be used to indicate the common grant channel. If N individual channels are deployed, the subscript x may range from 1 to N.

[0078] An individual grant may be made to one or more mobile stations, each of which gives permission to the identified mobile station to transmit on the R-ESCH at a specified T/P ratio or below. Making grants on the forward link will naturally introduce overhead that uses some forward link capacity. Various options for mitigating the overhead associated with grants are detailed herein, and other options will be apparent to those of skill in the art in light of the teachings herein.

[0079] One consideration is that mobile stations will be situated such that each experiences varying channel quality. Thus, for example, a high geometry mobile station with a good forward and reverse link channel may need a relatively low power for grant signal, and is likely to be able to take advantage of a high data rate, and hence is desirable for an individual grant. A low geometry mobile station, or one experiencing deeper fading, may require significantly more power to receive an individual grant reliably. Such a mobile station may not be the best candidate for an individual grant. A common grant for this mobile station, detailed below, may be less costly in forward link overhead.

[0080] In the example embodiment, a number of individual F-GCH channels are deployed to provide the corresponding number of individual grants at a particular time. The F-GCH channels are code division multiplexed. This facilitates the ability to transmit each grant at the power level required to reach just the specific intended mobile station. In an alternative embodiment, a single individual grant channel may be deployed, with the number of individual grants time multiplexed. To vary the power of each grant on a time multiplexed individual F-GCH may introduce additional

complexity. Any signaling technique for delivering common or individual grants may be deployed within the scope of the present invention.

[0081] In some embodiments, a relatively large number of individual grant channels (i.e. F-GCHs) are deployed to allow for a relatively large number of individual grants at one time. In such a case, it may be desirable to limit the number of individual grant channels each mobile station has to monitor. In one example embodiment, various subsets of the total number of individual grant channels are defined. Each mobile station is assigned a subset of individual grant channels to monitor. This allows the mobile station to reduce processing complexity, and correspondingly reduce power consumption. The tradeoff is in scheduling flexibility, since the scheduling base station may not be able to arbitrarily assign sets of individual grants (e.g., all individual grants can not be made to members of a single group, since those members, by design, do not monitor one or more of the individual grant channels). Note that this loss of flexibility does not necessarily result in a loss of capacity. For illustration, consider an example including four individual grant channels. The even numbered mobile stations may be assigned to monitor the first two grant channels, and the odd numbered mobile stations may be assigned to monitor the last two. In another example, the subsets may overlap, such as the even mobile stations monitoring the first three grant channels, and the odd mobile stations monitoring the last three grant channels. It is clear that the scheduling base station cannot arbitrarily assign four mobile stations from any one group (even or odd). These examples are illustrative only. Any number of channels with any configuration of subsets may be deployed within the scope of the present invention.

[0082] The remaining mobile stations, having made a request, but not receiving an individual grant, may be given permission to transmit on the R-ESCH using a common grant, which specifies a maximum T/P ratio that each of the remaining mobile stations must adhere to. The common F-GCH may also be referred to as the Forward Common Grant Channel (F-CGCH). A mobile station monitors the one or more individual grant channels (or a subset thereof) as well as the common F-GCH. Unless given an individual grant, the mobile station may transmit if a common grant is issued. The common grant indicates the maximum T/P ratio at which the remaining mobile stations (the common grant mobile stations) may transmit for the data with certain type of QoS.

[0083] In the example embodiment, each common grant is valid for a number of subpacket transmission intervals. Once receiving a common grant, a mobile station that has sent a request, but doesn't get an individual grant may start to transmit one or more

encoder packets within the subsequent transmission intervals. The grant information may be repeated multiple times. This allows the common grant to be transmitted at a reduced power level with respect to an individual grant. Each mobile station may combine the energy from multiple transmissions to reliably decode the common grant. Therefore, a common grant may be selected for mobile stations with low-geometry, for example, where an individual grant is deemed too costly in terms of forward link capacity. However, common grants still require overhead, and various techniques for reducing this overhead are detailed below.

[0084] The F-GCH is sent by the base station to each mobile station that the base station schedules for transmission of a new R-ESCH packet. It may also be sent during a transmission or a retransmission of an encoder packet to force the mobile station to modify the T/P ratio of its transmission for the subsequent subpackets of the encoder packet in case congestion control becomes necessary.

[0085] In the example embodiment, the common grant consists of 12 bits including a 3-bit type field to specify the format of the next nine bits. The remaining bits indicate the maximum allowed T/P ratio for 3 classes of mobiles as specified in the type field, with 3 bits denoting the maximum allowable T/P ratio for each class. The mobile classes may be based on QoS requirements, or other criterion. Various other common grant formats are envisioned, and will be readily apparent to one of ordinary skill in the art.

[0086] In the example embodiment, an individual grant comprises 12 bits including: 11 bits to specify the Mobile ID and maximum allowed T/P ratio for the mobile station being granted to transmit, or to explicitly signal the mobile station to change its maximum allowed T/P ratio, including setting the maximum allowed T/P ratio to 0 (i.e., telling the mobile station not to transmit the R-ESCH). The bits specify the Mobile ID (1 of 192 values) and the maximum allowed T/P (1 of 10 values) for the specified mobile. In an alternate embodiment, 1 long-grant bit may be set for the specified mobile. When the long-grant bit is set to one, the mobile station is granted permission to transmit a relatively large fixed, predetermined number (which can be updated with signaling) of packets on that ARQ channel. If the long-grant bit is set to zero, the mobile station is granted to transmit one packet. A mobile may be told to turn off its R-ESCH transmissions with the zero T/P ratio specification, and this may be used to signal the mobile station to turn off its transmission on the R-ESCH for a single subpacket transmission of a single packet if the long-grant bit is off or for a longer period if the long-grant bit is on.

[0087] In one example embodiment, the mobile station only monitors the F-GCH(s) from the Serving base station. If the mobile station receives an F-GCH message, then the mobile station follows the rate information in the F-GCH message and ignores the rate control bits. An alternative would be for the mobile station to use the rule that if any rate control indicator from a base station other than the serving base station indicates a rate decrease (i.e., the RATE_DECREASE command, detailed below) then the mobile station will decrease its rate even if the F-GCH indicates an increase.

[0088] In an alternative embodiment, the mobile station may monitor the F-GCH from all base stations or a subset of the base stations in its Active Set. Higher layer signaling indicates to the mobile station which F-GCH(s) to monitor and how to combine them at channel assignment, through a hand-off direction message, or other messages. Note that a subset of F-GCHs from different base stations may be soft combined. The mobile station will be notified of this possibility. After the possible soft combining of the F-GCHs from different base stations, there may still be multiple F-GCHs at any one time. The mobile station may then decide its transmit rate as the lowest granted rate (or some other rule).

R-PICH

[0089] The Reverse Pilot Channel (R-PICH) is transmitted from the mobile station to the base stations in the Active Set. The power in the R-PICH may be measured at one or more base stations for use in reverse link power control. As is well known in the art, pilot signals may be used to provide amplitude and phase measurements for use in coherent demodulation. As described above, the amount of transmit power available to the mobile station (whether limited by the scheduling base station or the inherent limitations of the mobile station's power amplifier) is split among the pilot channel, traffic channel or channels, and control channels. Additional pilot power may be needed for higher data rates and modulation formats. To simplify the use of the R-PICH for power control, and to avoid some of the problems associated with instantaneous changes in required pilot power, an additional channel may be allocated for use as a supplemental or secondary pilot. Although, generally, pilot signals are transmitted using known data sequences, as disclosed herein, an information bearing signal may also be deployed for use in generating reference information for demodulation. In an example embodiment, the R-RICH is used to carry the additional pilot power desired.

R-RICH

[0090] The Reverse Rate Indicator Channel (R-RICH) is used by the mobile station to indicate the transmission format on the reverse traffic channel, R-ESCH. This channel may be alternately referred to as the Reverse Packet Data Control Channel (R-PDCCH).

[0091] The R-RICH may be transmitted whenever the mobile station is transmitting a subpacket. The R-RICH may also be transmitted with zero-rate indication when the mobile station is idle on R-ESCH. Transmission of zero-rate R-RICH frames (an R-RICH that indicates the R-ESCH is not being transmitted) helps the base station detect that the mobile station is idle, maintain reverse link power control for the mobile station, and other functions.

[0092] The beginning of an R-RICH frame is time aligned with the beginning of the current R-ESCH transmission. The frame duration of R-RICH may be identical to or shorter than that of the corresponding R-ESCH transmission. The R-RICH conveys the transmit format of the concurrent R-ESCH transmission, such as payload, subpacket ID and ARQ Instance Sequence Number (AI_SN) bit, and CRC for error detection. An example AI_SN is a bit that flips every time a new packet is transmitted on a particular ARQ, sometimes referred to as a "color bit". This may be deployed for asynchronous ARQ, in which there is no fixed timing between subpacket transmissions of a packet. The color bit may be used to prevent the receiver from combining subpacket(s) for one packet with the subpacket(s) of an adjacent packet on the same ARQ channel. The R-RICH may also carry additional information.

R-ESCH

[0093] The Enhanced Reverse Supplemental Channel (R-ESCH) is used as the reverse link traffic data channel in the example embodiments described herein. Any number of transmission rates and modulation formats may be deployed for the R-ESCH. In an example embodiment, the R-ESCH has the following properties: Physical layer retransmissions are supported. For retransmissions when the first code is a Rate1/4 code, the retransmission uses a Rate1/4 code and energy combining is used. For retransmissions when the first code is a rate greater than 1/4, incremental redundancy is used. The underlying code is a Rate 1/5 code. Alternatively, incremental redundancy could also be used for all the cases.

[0094] Hybrid Automatic-Repeat-Request (HARQ) is supported for both autonomous and scheduled users, both of which may access the R-ESCH.

[0095] Multiple ARQ-channel synchronous operation may be supported with fixed timing between the retransmissions: a fixed number of sub-packets between consecutive sub-packets of same packet may be allowed. Interlaced transmissions are allowed as well. As an example, for 5ms frames, 4 channel ARQ could be supported with 3 subpacket delay between subpackets.

[0096] Table 1 lists example data rates for the Enhanced Reverse Supplemental Channel. A 5 ms subpacket size is described, and the accompanying channels have been designed to suit this choice. Other subpacket sizes may also be chosen, as will be readily apparent to those of skill in the art. The pilot reference level is not adjusted for these channels, i.e. the base station has the flexibility of choosing the T/P to target a given operating point. This max T/P value is signaled on the Forward Grant Channel. The mobile station may use a lower T/P if it is running out of power to transmit, letting HARQ meet the required QoS. Layer 3 signaling messages may also be transmitted over the R-ESCH, allowing the system to operate without the R-FCH and/or R-DCCH.

Table 1. Enhanced Reverse Supplemental Channel Parameters

Number of Bits per Encoder Packet	Number of 5-ms Slots	Data Rate (kbps)	Data Rate/ 9.6 kbps	Code Rate	Symbol Repetition Factor Before the Interleaver	Modulation	Walsh Channels	Number of Binary Code Symbols in All the Subpackets	Effective Code Rate Including Repetition
192	4	9.6	1.000	1/4	2	BPSK on I	+ + − −	6,144	1/32
192	3	12.8	1.333	1/4	2	BPSK on I	+ + − −	4,608	1/24
192	2	19.2	2.000	1/4	2	BPSK on I	+ + − −	3,072	1/16
192	1	38.4	4.000	1/4	2	BPSK on I	+ + − −	1,536	1/8
384	4	19.2	2.000	1/4	1	BPSK on I	+ + − −	6,144	1/16
384	3	25.6	2.667	1/4	1	BPSK on I	+ + − −	4,608	1/12
384	2	38.4	4.000	1/4	1	BPSK on I	+ + − −	3,072	1/8
384	1	76.8	8.000	1/4	1	BPSK on I	+ + − −	1,536	1/4
768	4	76.8	4.000	1/4	1	QPSK	+ + − −	12,288	1/16
768	3	102.4	5.333	1/4	1	QPSK	+ + − −	9,216	1/12
768	2	153.6	8.000	1/4	1	QPSK	+ + − −	6,144	1/8
768	1	307.2	16.000	1/4	1	QPSK	+ + − −	3,072	1/4
1,536	4	76.8	8.000	1/4	1	QPSK	+ −	24,576	1/16
1,536	3	102.4	10.667	1/4	1	QPSK	+ −	18,432	1/12
1,536	2	153.6	16.000	1/4	1	QPSK	+ −	12,288	1/8
1,536	1	307.2	32.000	1/4	1	QPSK	+ −	6,144	1/4
2,304	4	115.2	12.000	1/4	1	QPSK	+ + − − / + −	36,864	1/16
2,304	3	153.6	16.000	1/4	1	QPSK	+ + − − / +	27,648	1/12

Number of Bits per Encoder Packet	Number of 5-ms Slots	Data Rate (kbps)	Data Rate/ 9.6 kbps	Code Rate	Symbol Repetition Factor Before the Interleaver	Modulation	Walsh Channels	Number of Binary Code Symbols in All the Subpackets	Effective Code Rate Including Repetition
2,304	2	230.4	24.000	1/4	1	QPSK	++−−/+−	18,432	1/8
2,304	1	460.8	48.000	1/4	1	QPSK	++−−/+−	9,216	1/4
3,072	4	153.6	16.000	1/5	1	QPSK	++−−/+−	36,864	1/12
3,072	3	204.8	21.333	1/5	1	QPSK	++−−/+−	27,648	1/9
3,072	2	307.2	32.000	1/5	1	QPSK	++−−/+−	18,432	1/6
3,072	1	614.4	64.000	1/5	1	QPSK	++−−/+−	9,216	1/3
4,608	4	230.4	24.000	1/5	1	QPSK	++−−/+−	36,864	1/8
4,608	3	307.2	32.000	1/5	1	QPSK	++−−/+−	27,648	1/6
4,608	2	460.8	48.000	1/5	1	QPSK	++−−/+−	18,432	1/4
4,608	1	921.6	96.000	1/5	1	QPSK	++−−/+−	9,216	1/2
6,144	4	307.2	32.000	1/5	1	QPSK	++−−/+−	36,864	1/6
6,144	3	409.6	42.667	1/5	1	QPSK	++−−/+−	27,648	2/9
6,144	2	614.4	64.000	1/5	1	QPSK	++−−/+−	18,432	1/3
6,144	1	1228.8	128.000	1/5	1	QPSK	++−−/+−	9,216	2/3

[0097] In an example embodiment, turbo coding is used for all the rates. With R = 1/4 coding, an interleaver similar to the current cdma2000 reverse link is used. With R = 1/5 coding, an interleaver similar to the cdma2000 Forward Packet Data Channel is used.

[0098] The number of bits per encoder packet includes the CRC bits and 6 tail bits. For an encoder packet size of 192 bits, a 12-bit CRC is used; otherwise, a 16-bit CRC is used. The 5-ms slots are assumed to be separated by 15 ms to allow time for ACK/NAK responses. If an ACK is received, the remaining slots of the packet are not transmitted.

[0099] The 5ms subpacket duration, and associated parameters, just described, serve as an example only. Any number of combinations of rates, formats, subpacket repetition

options, subpacket duration, etc. will be readily apparent to those of skill in the art in light of the teaching herein. An alternate 10ms embodiment, using 3 ARQ channels, could be deployed. In one embodiment, a single subpacket duration or frame size is selected. For example, either a 5ms or 10ms structure would be selected. In an alternate embodiment, a system may support multiple frame durations.

F-CPCCH

[00100] The Forward Common Power Control Channel (F-CPCCH) may be used to power control various reverse link channels, including the R-ESCH when the F-FCH and the F-DCCH are not present, or when the F-FCH and the F-DCCH are present but not dedicated to a user. Upon channel assignment, a mobile station is assigned a reverse link power control channel. The F-CPCCH may contain a number of power control subchannels.

[00101] The F-CPCCH may carry a power control subchannel called the Common Congestion Control subchannel (F-OLCH). The exemplary congestion control subchannel is typically at a rate of 100 bps, though other rates can be used. The single bit (which may be repeated for reliability), referred to herein as the busy bit, indicates the mobile stations in autonomous transmission mode, or in the common grant mode, or both, whether to increase or decrease their rate. In an alternate embodiment, individual grant modes may be also be sensitive to this bit. Various embodiments may be deployed with any combination of transmission types responsive to the F-OLCH. This can be done in a probabilistic manner, or deterministically.

[00102] In one embodiment, setting the busy bit to '0' indicates that mobile stations responsive to the busy bit should decrease their transmission rate. Setting the busy bit to '1' indicates a corresponding increase in transmission rate. Myriad other signaling schemes may be deployed, as will be readily apparent to those of skill in the art, and various alternate examples are detailed below.

[00103] During channel assignment, the mobile station is assigned to these special power control channels. A power control channel may control all the mobiles in the system, or alternatively, varying subsets of the mobile stations may be controlled by one or more power control channels. Note that use of this particular channel for congestion control is but one example.

F-ACKCH

[00104] The Forward Acknowledgement Channel, or F-ACKCH, is used by a base station to acknowledge the correct reception of the R-ESCH, and can also be used to extend an existing grant. An acknowledgement (ACK) on the F-ACKCH indicates correct reception of a subpacket. Additional transmission of that subpacket by the mobile station is unnecessary. A negative acknowledgement (NAK) on the F-ACKCH allows the mobile station to transmit another subpacket, limited by a maximum allowed number of subpackets per packet.

[00105] In embodiments detailed herein, the F-ACKCH is used to provide positive or negative acknowledgment of a received subpacket, as well as an indication of whether or not rate control commands will be issued (described below with respect to the F-RCCH channel).

[00106] FIG. 5 is an example embodiment illustrating a tri-valued F-ACKCH. This example F-ACKCH consists of a single indicator, transmitted from one or more base stations to a mobile station, to indicate whether or not the transmission on the R-ESCH from the mobile station has been received correctly by the respective base station. In an example embodiment, the F-ACKCH indicator is transmitted by every base station in the Active Set. Alternatively, the F-ACKCH may be transmitted by a specified subset of the Active Set. The set of base stations sending the F-ACKCH may be referred to as the F-ACKCH Active Set. The F-ACKCH Active Set may be signaled by Layer 3 (L3) signaling to the mobile station and may be specified during channel assignment, in a Handoff Direction message (HDM), or via other techniques known in the art.

[00107] For example, F-ACKCH may be a 3-state channel with the following values: NAK, ACK_RC, and ACK_STOP. A NAK indicates that the packet from the mobile station has to be retransmitted (however, if the last subpacket has been sent, the mobile station may need to resend the packet using any of the techniques available, such as request/grant, rate control, or autonomous transmission). The mobile station may need to monitor the Rate Control indicator on the corresponding F-RCCH (detailed further below) if the NAK corresponds to last subpacket of a packet.

[00108] An ACK_RC indicates that no retransmissions of the packet from the mobile station are necessary, and the mobile station should monitor the Rate Control indicator on the corresponding F-RCCH. ACK_STOP also indicates no retransmission is necessary. However, in this case, the mobile station should revert to autonomous mode for the next transmission unless the mobile station receives a grant message on the F-GCH (detailed above).

[00109] L3 signaling may indicate whether or not the mobile station is to soft-combine the F-ACKCH indicators from different base stations in its Active Set. This may be equivalent to handling the power control bits in accordance with Revision C of IS-2000. For example, there may be an indicator, say ACK_COMB_IND, sent upon channel assignment and in handoff messages that would indicate whether the mobile station is to combine the F-ACKCH indicators from different base stations. A variety of techniques may be employed for transmitting the F-ACKCH, examples of which are given below. Some examples include a separate TDM channel, a TDM/CDM channel, or some other format.

[00110] In this example, there are two classes of results from monitoring the F-ACK channels, depending on whether the packet is acknowledged or not. If a NAK is received, a variety of options are available. The mobile station may send additional subpackets until the maximum number of subpackets has been sent. (In the example embodiment, the subpackets are sent using the same transmission format, whether initiated through autonomous or granted transmission, and whether or not subject to a rate control revision. In an alternate embodiment, the subpacket transmission format may be altered using any of the techniques disclosed herein). Subsequent to a NAK of the final subpacket, the mobile station may either take action relative to corresponding rate control commands (monitor the F-RCCH), stop transmitting according to the previous grant or rate control command (i.e. revert to autonomous transmission, if desired), or respond to a new received grant.

[00111] If an ACK is received, it may correspond to a rate control command or an indication to stop. If rate control is indicated, the rate control channel (F-RCCH) is monitored and followed. If the outcome is to stop, then the mobile station does not follow the rate control indicators on the F-RCCH and reverts to the autonomous mode (transmitting up to the assigned maximum autonomous rate). If an explicit grant is received at the same time as an ACK_STOP, then the mobile station follows the command in the explicit grant.

[00112] For example, first consider a single Active Set Member or the case when the indicators from all sectors are the same (and are so indicated by ACK_COMB_IND). In this case, there is a single resultant indicator. When the mobile station receives a NAK (indicator not transmitted), then the mobile station retransmits the next subpacket (at the appropriate time). If the mobile station does not receive an ACK for the last subpacket, then the mobile station goes on to the next packet (the errant packet may be

retransmitted according to whatever retransmission algorithm is being followed). However, the mobile station takes this as a rate control indication (i.e. monitors the rate control channel).

[00113] In this example, a general rule is as follows (applicable to both a single Active Set member and multiple distinctive F-ACKCH Active Set members). If any indicator is an ACK_STOP or ACK_RC, the result is an ACK. If none of the indicators is an ACK_STOP or ACK_RC, the result is a NAK. Then, in relation to rate control, if any indicator is an ACK_STOP, the mobile station will stop (i.e. revert to autonomous mode, or respond to a grant, if any). If no indicator is an ACK_STOP and at least one indicator is an ACK_RC, decode the indicator on the rate control channel (F-RCCH) of the corresponding base station. If the last subpacket has been transmitted, and all indicators are NAK, decode the indicator on the rate control channels (F-RCCH) of all the base stations. Responding to the rate control commands in these scenarios is detailed further below with respect to the description of F-RCCH.

[00114] An ACK_RC command, combined with the rate control channel, may be thought of as a class of commands referred to as ACK-and-Continue commands. The mobile station may continue transmitting subsequent packets, continuing in accordance with the various rate control commands that may be issued (examples detailed below). An ACK-and-Continue command allows the base station to acknowledge successful reception of a packet and, at the same time, permit the mobile station to transmit using the grant that led to the successfully received packet (subject to possible revisions according to the rate control commands). This saves the overhead of a new grant.

[00115] In the embodiment of the F-ACKCH, depicted in FIG. 5, a positive value for the ACK_STOP symbol, a NULL symbol for the NAK, and a negative value for the ACK_RC symbol is used. On-off keying (i.e., not sending NAK) on the F-ACKCH allows the base stations (especially non-scheduling base stations) an option of not sending an ACK when the cost (required power) of doing so is too high. This provides the base station a trade-off between the forward link and reverse link capacity, since a correctly received packet that is not ACKed will likely trigger a re-transmission at a later point in time.

[00116] A variety of techniques for sending the F-ACKCH may be deployed within the scope of the present invention. Individual signals for each mobile station may be combined in a common channel. For example, acknowledgement responses for a plurality of mobile stations may be time multiplexed. In an example embodiment, up to

96 Mobile IDs can be supported on one F-ACKCH. Additional F-ACKCHs may be deployed to support additional Mobile IDs.

[00117] Another example is to map a plurality of acknowledgement signals for a plurality of mobile stations onto a set of orthogonal functions. A Hadamard Encoder is one example of an encoder for mapping onto a set of orthogonal functions. Various other techniques may also be deployed. For example, any Walsh Code or other similar error correcting code may be used to encode the information bits. Different users may be transmitted to at different power levels if independent each subchannel has an independent channel gain. The exemplary F-ACKCH conveys one dedicated tri-valued flag per user. Each user monitors the F-ACKCH from all base stations in its Active Set (or, alternatively, signaling may define a reduced active set to reduce complexity).

[00118] In various embodiments, two channels are each covered by a 128-chip Walsh cover sequence. One channel is transmitted on the I channel, and the other is transmitted on the Q channel. Another embodiment of the F-ACKCH uses a single 128-chip Walsh cover sequence to support up to 192 mobile stations simultaneously. An example embodiment uses a 10-ms duration for each tri-valued flag.

[00119] To review, when the mobile station has a packet to send that requires usage of the R-ESCH, it may request on the R-REQCH. The base station may respond with a grant using an F-GCH. However, this operation may be somewhat expensive. To reduce the forward link overhead, F-ACKCH may send the ACK_RC flag, which extends the existing grant (subject to rate control) at low cost by the scheduling base station (or others, when soft handoff grants from multiple base stations are supported). This method works for both individual and common grants. ACK_RC is used from the granting base station (or base stations), and extends the current grant for one more encoder packet on the same ARQ channel (subject to rate control).

[00120] Note that, as shown in FIG. 4, not every base station in the Active Set is required to send back the F-ACKCH. The set of base stations sending the F-ACKCH in soft handoff may be a subset of the Active Set. Example techniques for transmitting the F-ACKCH are disclosed in co-pending US Patent Application No. 10/611,333, entitled "CODE DIVISION MULTIPLEXING COMMANDS ON A CODE DIVISION MULTIPLEXED CHANNEL", filed June 30, 2003, assigned to the assignee of the present invention.

F-RCCH

[00121] The Forward Rate Control Channel (F-RCCH) is transmitted from one or more base stations to a mobile station to signal a rate adjustment for the next transmission. A mobile station may be assigned to monitor the indicator from every member of the F-ACKCH Active Set or a subset thereof. For clarity, the set of base stations sending the F-RCCH to be monitored by the mobile station will be referred to as the F-RCCH Active Set. The F-RCCH Active Set may be signaled by Layer 3 (L3) signaling, which may be specified during channel assignment, in a Hand-Off Direction message (HDM), or any of various other ways known to those of skill in the art.

[00122] FIG. 6 depicts an exemplary F-RCCH. The F-RCCH is a 3-state channel with the following values: RATE_HOLD, indicating the mobile station can transmit the next packet at no more than the same rate of current packet; RATE_INCREASE, indicating that the mobile station can, either deterministically or probabilistically, increase the maximum rate to transmit the next packet relative to the transmit rate of current packet; and RATE_DECREASE, indicating that the mobile station can, either deterministically or probabilistically, decrease the maximum rate to transmit the next packet relative to the transmit rate of current packet.

[00123] L3 signaling may indicate whether or not the mobile station is to combine the Rate Control indicators from different base stations. This is similar to what is done with the power control bits in IS-2000 Rev. C. Thus, there would be an indicator, for example RATE_COMB_IND, sent upon channel assignment, and in handoff messages, that would indicate whether the mobile station is to soft-combine the F-RCCH bits from different base stations. Those of skill in the art will recognize that there are many formats for transmitting channels such as the F-RCCH, including separate TDM channels, combined TDM/CDM channels, or other formats.

[00124] In various embodiments, various rate control configurations are possible. For example, all mobile stations may be controlled by a single indicator per sector. Alternatively, each mobile station may be controlled by a separate indicator per sector dedicated to each mobile station. Or, groups of mobile stations may be controlled by their own assigned indicator. Such a configuration allows mobile stations with the same maximum QoS grade to be assigned the same indicator. For example, all mobile stations whose only stream is designated "best effort" may be controlled by one assigned indicator, thus allowing a reduction in load for these best effort streams.

[00125] In addition, signaling may be used to configure a mobile station so that the mobile station only pays attention to the F-RCCH indicator from the Serving Base

Station or from all base stations in the F-RCCH Active Set. Note that if the mobile station is only monitoring the indicator from the Serving Base Station and RATE_COMB_IND specifies that the indicator is the same from multiple base stations, then the mobile station may combine all indicators in the same group as the Serving Base Station before making a decision. The set of base stations with distinctive rate control indicators in use at any time will be referred to as the F-RCCH Current Set. Thus, if the mobile station is configured so that the mobile station only pays attention to the F-RCCH indicator from the Serving Base Station, then the size of the F-RCCH Current Set is 1.

[00126] It is envisioned that the usage rules for the F-RCCH may be adjusted by the base station. The following is an example set of rules for a mobile station with a single-member F-RCCH Current Set. If a RATE_HOLD is received, the mobile station does not change its rate. If a RATE_INCREASE is received, the mobile station increases its rate by one (i.e. one rate level, examples of which are detailed above in Table 1). If a RATE_DECREASE is received, the mobile station decreases its rate by one. Note that the mobile station monitors these indicators only when circumstances dictate (i.e. the action as a result of the ACK process, detailed further below, indicating rate control is active).

[00127] The following is an example set of rules for a mobile station with multiple F-RCCH Current Set members. The simple rule of increasing/decreasing the rate by 1 rate is modified. If any ACK_STOP is received, the mobile station reverts to autonomous rates. Otherwise, if any indicator is a RATE_DECREASE, the mobile station decreases its rate by one. If no indicator is a RATE_DECREASE, and at least one base station has an action of rate control (as a result of the ACK process) that indicates RATE_HOLD, then the mobile station maintains the same rate. If no indicator is a RATE_DECREASE, no base station indicates rate control and RATE_HOLD, and at least one base station has an action of rate control and an indication of RATE_INCREASE; then the mobile station increases its rate by one.

Example Combined Grant, ARQ, and Rate Control Command Embodiments

[00128] To summarize some of the aspects introduced above, mobile stations may be authorized to make autonomous transmissions, which, while perhaps limited in throughput, allow for low delay. In such a case, the mobile station may transmit

without request up to a max R-ESCH T/P ratio, T/P_{Max_auto}, which may be set and adjusted by the base station through signaling.

[00129] Scheduling may be determined at one or more scheduling base stations, and allocations of reverse link capacity may be made through grants transmitted on the F-GCH at a relatively high rate. Additionally, rate control commands may be used to modify previously granted transmissions or autonomous transmissions, with low overhead, thus tuning the allocation of reverse link capacity. Scheduling may thus be employed to tightly control the reverse link load and thus protect voice quality (R-FCH), DV feedback (R-CQICH) and DV acknowledgement (R-ACKCH).

[00130] An individual grant allows detailed control of a mobile station's transmission. Mobile stations may be selected based upon geometry and QoS to maximize throughput while maintaining required service levels. A common grant allows efficient notification, especially for low geometry mobile stations.

[00131] The F-ACKCH channel in combination with the F-RCCH channel effectively implements "ACK-and-Continue" commands, which extend existing grants at low cost. (The continuation may be rate controlled, as described above, and detailed further below). This works with both individual grants and common grants. Various embodiments and techniques for scheduling, granting, and transmitting on a shared resource, such as a 1xEV-DV reverse link, are disclosed in co-pending US Patent Application No. 10/646,955, entitled "SCHEDULED AND AUTONOMOUS TRANSMISSION AND ACKNOWLEDGEMENT", filed August 21, 2003, assigned to the assignee of the present invention, and incorporated by reference herein.

[00132] FIG. 7 depicts example method 700 that one or more base stations may deploy to allocate capacity in response to requests and transmissions from one or more mobile stations. Note that the order of blocks shown is but one example, and the order of the various blocks may be interchanged or combined with other blocks, not shown, without departing from the scope of the present invention. The process starts at block 710. The base station receives any requests for transmission that may be transmitted by one or more mobile stations. As method 700 may be iterated indefinitely, there may be prior requests also received that may not have been granted, which may be combined with new requests to estimate the amount of demand for transmission according to requests.

[00133] In block 720, one or more mobile stations may transmit subpackets that are received by the base station. These transmitted subpackets may have been transmitted in accordance with previous grants (potentially modified with previous rate control

commands) or autonomously (also potentially modified with previous rate control commands). The number of autonomous transmissions, the number of registered mobile stations, and/or other factors may be used to estimate the amount of demand for autonomous transmission.

[00134] In block 730, the base station decodes any received subpackets, optionally soft-combining with respective previously received subpackets, to determine whether the packets have been received without error. These decisions will be used to send a positive or negative acknowledgement to the respective transmitting mobile stations. Recall that HARQ may be used for packet transmission on the R-ESCH. That is, a packet may be transmitted up to certain number of times until it is received correctly by at least one base station. At each frame boundary, each base station decodes the R-RICH frame and determines the transmit format on the R-ESCH. A base station may also make this determination using the current R-RICH frame and previous R-RICH frames. Alternatively, a base station may also make the determination using other information extracted from a Reverse Secondary Pilot Channel (R-SPICH) and/or the R-ESCH. With the determined transmit format, the base station attempts to decode the packet on the R-ESCH, using previously received subpackets, as appropriate.

[00135] In block 740, the base station performs scheduling. Any scheduling technique may be deployed. The base station may factor in demand for transmission according to requests, anticipated autonomous transmission, estimates of current channel conditions, and/or various other parameters in order to perform scheduling to allocate the shared resource (reverse link capacity, in this example). Scheduling may take various forms for the various mobile stations. Examples include making a grant (allocating according to a request, increasing a previous grant or reducing a previous grant), generating a rate control command to increase, decrease, or hold a previously granted rate or autonomous transmission, or ignoring a request (relegating the mobile station to autonomous transmission).

[00136] In step 750, the base station processes the received transmissions for each mobile station. This may include, among other functions, acknowledging received subpackets, and conditionally generating grants in response to requests for transmission. FIG. 8 depicts example method 750 of generating grants, acknowledgements, and rate control commands. It is suitable for deployment in the example method 700 depicted in FIG. 7, and may be adapted for use with other methods, as will be readily apparent to

those of ordinary skill in the art. Method 750 may be iterated for each active mobile station during each pass through method 700, as described above.

[00137] In decision block 805, if a subpacket for the mobile station currently being processed has not been received, proceed to block 810. There is no acknowledgement necessary, and no rate control command to issue. Neither the F-ACKCH nor the F-RCCH need to be transmitted, and both symbols may be DTXed (not transmitted). In decision block 815, if a request has been received, proceed to decision block 820. Otherwise the process may stop.

[00138] In decision block 820, if a grant has been determined for this mobile station during scheduling, proceed to block 825 to transmit the grant on the appropriate F-GCH. Then the process may stop. The mobile station may transmit in accordance with this grant during the next appropriate frame (timing examples are detailed below with respect to FIGS. 10-12).

[00139] Returning to decision block 805, if a subpacket from the mobile station was received, proceed to decision block 830. (Note that it is possible for a subpacket and a request to be received, in which case both branches out of decision block 805 may be performed for a mobile station, details not shown for clarity of discussion).

[00140] In decision block 830, if the received subpacket was decoded correctly, an ACK will be generated. Proceed to decision block 835. If rate control is desired (including a rate hold, i.e. "Continue"), proceed to block 845. If no rate control is desired, proceed to block 840. In block 840, an ACK_STOP is transmitted on F-ACKCH. F-RCCH need not be transmitted, i.e. a DTX may be generated. If no grant is generated at this time, the mobile station will be relegated to autonomous transmission (or must stop, if autonomous transmission is not available, or not deployed). Alternatively, a new grant may be issued which will override the stop command. Proceed to decision block 820 to process this decision, as described above.

[00141] In block 845, rate control was indicated. As such, an ACK_RC will be transmitted on F-ACKCH. Proceed to decision block 850. If an increase is desired, transmit a RATE_INCREASE on F-RCCH. Then the process may stop. If an increase is not desired, proceed to decision block 860. In decision block 860, if a decrease is desired, transmit a RATE_DECREASE on F-RCCH. Then the process may stop. Otherwise, transmit a RATE_HOLD on F-RCCH. In this example, a hold is indicated by a DTX. Then the process may stop.

[00142] Returning to decision block 830, if the received subpacket was not decoded correctly, a NAK will be generated. Proceed to block 875 to transmit a NAK on F-ACKCH. In this example, a NAK is indicated by a DTX. Proceed to decision block 880 to determine if the received subpacket was the last subpacket (i.e. the maximum number of subpacket retransmissions has been reached). If not, in this example, the mobile station may retransmit according to the previous transmission format. A DTX may be transmitted on F-RCCH, as indicated in block 895. (Alternative embodiments may perform alternate signaling in this case, examples of which are described below.) Then the process may stop.

[00143] If the received, and NAKed, subpacket is the last subpacket, proceed from decision block 880 to decision block 885 to determine if rate control (including a hold) is desired. This is an example technique for extending the previous grant or autonomous transmission (including previous rate control, if any), with low overhead. If no rate control is desired, a DTX is generated for the F-RCCH. In this example, the mobile station will transmit the next subpacket. Similar to decision block 835, if a new grant is not generated for the mobile station, the mobile station will be relegated to autonomous transmission (if available). Alternatively, a new grant may be generated, which will dictate the available transmission for the mobile station. Proceed to decision block 820 to perform this determination, as described above.

[00144] In decision block 885, if rate control is desired, proceed to decision block 850. An increase, decrease, or hold may be generated for transmission on F-RCCH, as described above. Then the process may stop.

[00145] In summary, if a packet is received correctly, the base station may send positive acknowledgement and conditionally may send a rate control message to the mobile station.

[00146] The base station may send an ACK_STOP (on F-ACKCH) to signal that the packet has been delivered and the mobile station reverts to autonomous mode for the next transmission. The base station may also send a new grant, if desired. The mobile station may transmit up to the granted rate for the next transmission. In either case, F-RCCH is DTXed. In one embodiment, only a serving (or granting) base station may generate grants. In an alternate embodiment, one or more base stations may generate grants (details for handling this option are detailed below).

[00147] The base station may send ACK_RC (on F-ACKCH) and RATE_HOLD (on F-RCCH) to signal that the packet was delivered and that the maximum rate the mobile station may transmit the next packet is same as the transmit rate of the current packet.

[00148] The base station may send ACK_RC (on F-ACKCH) and RATE_INCREASE (on F-RCCH) to signal that the packet was delivered and that mobile station may increase the maximum rate for the next packet transmission relative to the transmit rate of the current packet. The mobile station may increase the rate following certain rules known to both base station and the mobile station. The increase may be either deterministic or probabilistic. Those of skill in the art will recognize myriad rules for increasing a rate.

[00149] The base station may send ACK_RC (on F-ACKCH) and RATE_DECREASE (on F-RCCH) to signal that the packet was delivered and that the mobile station should decrease the maximum rate for the next packet transmission relative to the transmit rate of the current packet. The mobile station may decrease the rate following certain rules known to both the base station and the mobile station. The decrease may be either deterministic or probabilistic. Those of skill in the art will recognize myriad rules for decreasing a rate.

[00150] If a packet is not received successfully by the base station, and the packet may be further retransmitted (i.e., not the last subpacket), the base station sends a NAK on F-ACKCH. Note that F-RCCH is DTXed in this example.

[00151] If further retransmission is not allowed for the packet (i.e., last subpacket), the following are possible actions the base station may take. The base station may send NAK (on F-ACKCH) and a grant message simultaneously on the F-GCH to signal the mobile station that the packet was not delivered and that the mobile station may transmit up to the granted rate for the next transmission. F-RCCH is DTXed in this case. In one embodiment, only a serving (or granting) base station may generate grants. In an alternate embodiment, one or more base stations may generate grants (details for handling this option are detailed below).

[00152] The base station may also send a NAK (on F-ACKCH) and RATE_HOLD (on F-RCCH) to signal that the packet was not delivered and that the maximum rate the mobile station may transmit the next packet is the same as the transmit rate of the current packet.

[00153] The base station may also send a NAK (on F-ACKCH) and RATE_INCREASE (on F-RCCH) to signal that the packet was not delivered and that the mobile station may

increase the maximum rate for next packet transmission relative to the transmit rate of the current packet. The mobile station may increase the rate following certain rules known to both the base station and the mobile station. The increase can be either deterministic or probabilistic.

[00154] The base station may also send a NAK (on F-ACKCH) and RATE_DECREASE (on F-RCCH) to signal that the packet was not delivered and that the mobile station should decrease the maximum rate for the next packet transmission relative to the transmit rate of the current packet. The mobile station may decrease the rate following certain rules known to both the base station and the mobile station. The decrease may be either deterministic or probabilistic.

[00155] In an alternative embodiment (details not shown in FIG. 8), an alternative for NAK and stop may be created. For example, in the above scenario, a DTX on F-RCCH corresponding to a NAK cannot be distinguished from a "NAK-and-hold". If it is desired to have a command to force a stop (or reversion to autonomous transmission), the base station could also use NAK and rate control, prior to the last subpacket, to indicate that a rate hold (or increase, or decrease) on the final subpacket is to mean stop. For example, any one of the rate control commands (i.e. RATE_INCREASE, RATE_DECREASE, or RATE_HOLD) may be assigned to mean stop in this special case. The mobile station will know when the last subpacket was transmitted, and can then parse the rate control commands accordingly. When the base station knows that if the final subpacket transmission should be followed by a stop in the event of a NAK, the selected rate control command may be issued with a NAK of a previous subpacket. A mobile station receiving the identified rate control command along with a NAK of a subpacket (not the final) would know that a NAK (and RATE_HOLD, for example) on the final subpacket would mean that any previous grant would be rescinded, and the mobile station must revert to autonomous transmission. The rate control commands not used for this purpose (i.e. RATE_INCREASE or RATE_DECREASE) transmitted with a final subpacket NAK would still be available. An alternative would be to transmit a grant with a zero (or lowered) rate along with the final NAK, although this would require additional overhead. Those of skill in the art will readily tradeoff these alternatives in accordance with the likelihood of "NAK-and-Stop" with other possibilities. The required overhead may then be optimized based on the probabilities of the various events.

[00156] FIG. 9 depicts example method 900 for a mobile station to monitor and respond to grants, acknowledgements, and rate control commands. This method is suitable for deployment in one or more mobile stations for use in conjunction with one or more base stations employing method 700, as described above, as well as other base station embodiments.

[00157] The process begins in block 910. The mobile station monitors the F-GCH, F-ACKCH, and F-RCCH. Note that in various embodiments, as described above, a mobile station may monitor one or more of these channels. For example, there may be multiple grant channels, and each mobile station may monitor one or more of them. Note also that each of these channels may be received from one base station, or more than one when the mobile station is in soft handoff. A channel may incorporate messages or commands directed to multiple mobile stations, and so a mobile station may extract the messages or commands specifically directed to it.

[00158] Other rules may be employed to allow a mobile station to conditionally monitor one or more of the control channels. For example, as described above, the F-RCCH may not be transmitted when an ACK_STOP is issued. Thus, in such a case, the mobile station need not monitor the F-RCCH when an ACK_STOP is received. A rule may be specified that a mobile station looks for grant messages and/or rate control commands only if the mobile station has sent a request to which those messages may be responsive.

[00159] In the following description of FIG. 9, it is assumed that the mobile station has previously transmitted a subpacket, for which an acknowledgement (including potential grants or rate control commands) response is expected. If a request has not been previously granted, the mobile station may still monitor for a grant in response to a previously transmitted request. Those of skill in the art will readily adapt method 900 to account for this situation. These, and other potential mobile station processing blocks, have been omitted for clarity of discussion.

[00160] Beginning in decision block 915, the processing of the F-ACKCH begins. The mobile station extracts the information on all the F-ACKCH channels it monitors. Recall that there may be an F-ACKCH between the mobile station and every member of its F-ACKCH Active Set. Some of the F-ACKCH commands may be soft-combined, as specified via L3 signaling. If a mobile station receives at least one positive acknowledgement, either ACK_RC or ACK_STOP (on F-ACKCH), the current packet has been received correctly, and additional subpackets need not be transmitted. The allowable rate for transmission of the next packet, if any, needs to be determined.

[00161] In decision block 915, if an ACK_STOP has been received, the mobile station knows that the previously transmitted subpacket has been received correctly, and that rate control commands need not be decoded.

[00162] In decision block 920, the mobile station determines if a grant has been received on an F-GCH. If so, the mobile station transmits the next packet according to the grant, as indicated in block 930. In one embodiment, only one granting base station makes grants. If ACK_STOP and a grant message are received from the base station, the mobile station transmits a new packet on the same ARQ channel at any rate equal to or below the granted rate.

[00163] In an alternate embodiment, more than one base station may send a grant. If the base stations coordinate the grant, and send an identical message, the mobile station may soft combine those grants. Various rules may be deployed to handle the cases when differing grants are received. One example is to have the mobile station transmit at the lowest rate indicated in a received grant, to avoid excessive interference in the cell corresponding to the respective granting base station (including an ACK_STOP without a corresponding grant – indicating that transmission should revert to autonomous mode). Various other alternatives will be apparent to those of skill in the art. If a grant was not received in decision block 920, the mobile station must return to autonomous rate, as shown in block 925. Then the process may stop.

[00164] Returning to decision block 915, if an ACK_STOP is not received, proceed to decision block 940. If an ACK_RC is received, the mobile station monitors the corresponding F-RCCH of base stations from which positive acknowledgement(s) are received, if any. Note that there may not be an F-RCCH between a base station and the mobile station, as the F-RCCH Active Set is a subset of the F-ACKCH Active Set. Note again that when a mobile station receives an F-ACKCH from multiple base stations, the corresponding messages may be in conflict. For example, one or more ACK_STOP commands may be received, one or more ACK_RC commands may be received, one or more grants may be received, or any combination thereof. Those of skill in the art will recognize various rules for implementing to accommodate any of the possibilities. For example, the mobile station may determine the lowest possible transmission permission (which may be from either an ACK_STOP with no grant, an ACK_RC with a decrease, or a grant with a lower value) and transmit accordingly. This is similar to a technique known as an "OR-of-Downs" rule. Such a technique may be used to strictly avoid excessive interference with neighbor cells. Or, one or more base

stations may have a priority assigned with them, such that one or more base station may have the ability to trump others (with conditions attached, perhaps). For example, a scheduling (or granting) base station may have some priority over other base stations in soft handoff. Other rules are also anticipated. (Recall that one or more NAKs may also be received, but the mobile station need not retransmit. However, a mobile station may incorporate rate control commands or grants, in similar fashion, from a NAKing base station, if desired.) To facilitate the discussion herein, when it is said that a mobile station determines whether an ACK_STOP, ACK_RC, NAK, or grant is received, it may be the result of applying a desired set of rules to a number of commands received, and the outcome is the command identified.

[00165] If an ACK_RC has been received, proceed to decision block 945 to begin determining what type of rate control command should be followed. If an increase is indicated, proceed to block 950. The next transmission may be transmitted on the same ARQ channel at an increased rate from the current rate. Then the process may stop. Again, the increase may be deterministic or probabilistic. Also, a RATE_INCREASE may not necessarily result in immediate rate increase but would increase the transmission rate from the mobile station in the future (i.e., a credit-like algorithm is used at the mobile station), or a RATE_INCREASE may result in an increase spanning multiple rates. In an example credit algorithm, a mobile station maintains an internal "balance/credit" parameter. Whenever it receives RATE_INCREASE but can't increase its rate (because it is either running out of power or data), the mobile station increases the parameter. When power or data becomes available for the mobile station, it may use the stored "credit/balance" in selecting data rates. Various ways of increasing the rate will be apparent to those of skill in the art.

[00166] If an increase is not indicated in decision block 945, proceed to decision block 955 to determine if a decrease is indicated. If a decrease is indicated, proceed to block 960. The next transmission may be transmitted on the same ARQ channel at a decreased rate from the current rate. Then the process may stop. Again, the decrease may be deterministic or probabilistic. Also, a RATE_DECREASE may not necessarily result in immediate rate decrease but would decrease the transmission rate from the mobile station in the future (i.e., a credit-like algorithm is used at the mobile station), or a RATE_DECREASE may result in a decrease spanning multiple rates. When an example credit algorithm is used in the RATE_DECREASE context, when a mobile station gets a RATE_DECREASE but doesn't follow it for some reason (e.g. urgent

data that needs to be sent out), it gets a negative credit, and this negative credit needs to be paid back later on, in a sense. Various ways of decreasing the rate will be apparent to those of skill in the art.

[00167] If neither an increase nor decrease is indicated, a RATE_HOLD has been received. The mobile station may transmit the next packet at a maximum rate equal to the rate of the current packet, as indicated in block 965. Then the process may stop.

[00168] Returning to decision block 940, if neither type of ACK has been identified, a NAK will be determined to have been received. In decision block 970, if retransmission is still possible for the packet (i.e., the current subpacket was not the last subpacket), the mobile station retransmits the subpacket on the same ARQ channel with the subpacket ID incremented, as depicted in block 980.

[00169] In decision block 970, if the current packet was the last subpacket, the mobile station has run out of retransmissions for the packet. Proceed to decision block 975 to determine if a grant has been received (in similar fashion as described above with respect to block 920). If a grant message is designated to the mobile station (whether from a single base station, or more than one, as discussed above), the mobile station may transmit a new packet on the same ARQ channel at a rate equal to or below the granted rate. Proceed to block 930, described above.

[00170] In decision block 975, if a grant has not been received, the mobile station may monitor the F-RCCH Active Set, obtain rate control commands, and decide the maximum rate allowed for next packet transmission on the same ARQ channel. The selection of rates when more than one rate control command is received may be made as described above. Proceed to decision block 945 and continue as described above.

[00171] Various other techniques may be employed by an exemplary embodiment of a mobile station. A mobile station may monitor the number of packet erasures (i.e., no positive acknowledgement after the last subpacket). A measurement may be made by counting the number of consecutive packet erasures or counting the number of erased packets within a window (i.e. a sliding window). If the mobile station recognizes too many packets have been erased, it may reduce its transmit rate even if the rate control commands indicate another command (i.e. RATE_HOLD or RATE_INCREASE).

[00172] In one embodiment, a grant message may have higher priority than a rate control bit. Alternatively, a grant message may be treated with the same priority as a rate control bit. In such a case, rate determination may be modified. For example, if no grant message is designated to the mobile station, the rate for next transmission is

determined from all rate control commands (RATE_INCREASE, RATE_HOLD, RATE_DECREASE, and ACK_STOP) using an "OR-of-DOWN" or similar rule. When a grant is also received, a rate for next transmission may determined from all rate control commands (RATE_INCREASE, RATE_HOLD, RATE_DECREASE, and ACK_STOP) using an "OR-of-DOWN" or similar rule, the result of which is compared with a granted rate and the smaller rate chosen.

[00173] Signaling may be deployed to configure the mobile station so that the mobile station only monitors the F-RCCH indicator from either the serving base station or from all base stations in the F-RCCH Active Set. For example, when RATE_COMB_IND may specify that a rate control command is the same from multiple base stations, then the mobile station may combine all indicators in the identified group before making a decision. The number of distinctive indicators in use at any time may be indicated as the F-RCCH Current Set. In one example, a mobile station may be configured to monitor only the F-RCCH indicator from the Serving base station, in which case the size of the F-RCCH Current Set is 1.

[00174] In addition, as described above, various rules may be deployed for adjusting rates in response to commands on the F-RCCH. Any of these rules may be adjusted by signaling from the base station. In one example, there may be a set of probabilities and step sizes used in determining whether the mobile station increases or decreases its rate, and by how much. These probabilities and possible rate step sizes may be updated through signaling, as necessary.

[00175] Method 900 may be adapted to include the various alternatives described for a base station employing method 750, described above. For example, in one embodiment, a NAK and stop command is not explicitly defined, as a DTX on the F-RCCH along with a NAK indicates a rate hold. In an alternate embodiment, NAK and stop functionality may be deployed responding to any of the alternate techniques described above for method 750. Also, as noted above with respect to method 750, in the example embodiment, rate control or grant based change of rate is carried out on packet boundaries. It is anticipated that the methods described may be modified to incorporate inter-subpacket rate changes as well.

[00176] It will clear to those of skill in the art in light of the teaching herein that any of the procedures and features described herein may be combined in various ways. For example, a mobile station may only be controlled by the primary base station via grants but not controlled by other base stations via rate control bits. Alternatively, the mobile

station may be controlled via grants from all the base stations, or a subset of base stations in its Active Set. Some F-GCHs may be soft combined. The mode in which a mobile station operates may be set up via L3 signaling during channel assignment or via other messages during a packet data call.

[00177] As another example, if a packet is received correctly, the primary base station may send either ACK_STOP or ACK_RC. The rate control commands may not be used, thus ACK_RC may be used to mean "ACK and continue" for this mode. In this context "ACK and continue" indicates that the mobile station may transmit a new packet at the same rate as the packet that is being acknowledged. As before, if ACK_STOP is sent, the base station may also send an overriding grant on F-GCH designated to the MS. In this example, a NAK will indicate "NAK and stop", unless a corresponding grant is transmitted with the NAK. In this scenario, non-primary base stations also send ACK_STOP or ACK_RC, where ACK_RC is not accompanied by a rate control command, and indicates "ACK and continue".

[00178] In another example special mode, incorporating a subset of the features described, the mobile station may be controlled via rate control bits only (from base stations in its F-RCCH Active Set). This mode may be set up via L3 signaling during channel assignment or other messages during a packet data call. In this mode, a base station sends NAK if a packet is not received successfully. When a packet is received correctly, a base station sends either ACK_STOP or ACK_RC along with the F-RCCH (RATE_HOLD, RATE_INCREASE, or RATE_DECREASE). A NAK after the last subpacket may be accompanied with the F-RCCH (RATE_HOLD, RATE_INCREASE, or RATE_DECREASE).

[00179] FIGS. 10-12 show examples illustrating timing of various channels described herein. The examples do not represent any specific choice of frame length, but illustrate relative timing of the grant, ACK, and rate control (RC) indicators. The ACK indicator, RC indicator, and the grant occur during the same time interval such that the mobile station receives the ACK, RC and grant information at roughly the same time for application to the next packet transmission. In these examples, the mobile station need not monitor the RC indicators except when it receives an acknowledgement or when all subpackets have been transmitted (as described in example embodiments above). A mobile station monitors the ACK bit assigned to it and to the RC indicator corresponding to the particular ARQ sequence. For example, if there are four ARQ sequences, and the mobile station is transmitting on all ARQ sequences, then the mobile

station monitors the ACK indicator every frame and to the RC indicator (as applicable) every frame. Empty frames between various transmissions are introduced to allow time for a base station or mobile station, as applicable, to receive and decode requests, subpacket transmissions, grants, acknowledgements, and rate control commands.

[00180] Note that these timing diagrams are not exhaustive, but serve only to illustrate various aspects described above. Those of skill in the art will recognize myriad combinations of sequences.

[00181] FIG. 10 depicts timing for an example embodiment with combined acknowledgement and rate control channels. A mobile station transmits a request for transmission on the R-REQCH. A base station subsequently transmits a grant on the F-GCH in response to the request. The mobile station then transmits a first subpacket using parameters in accordance with the grant. The subpacket is not decoded correctly at a base station, as indicated by the strikeout of the subpacket transmission. The base station transmits an ACK/NAK transmission on the F-ACKCH along with a rate control command on the F-RCCH. In this example, a NAK is transmitted, and the F-RCCH is DTXed. The mobile station receives the NAK and retransmits the second subpacket in response. This time, the base station correctly decodes the second subpacket, and again sends an ACK/NAK transmission on the F-ACKCH along with a rate control command on the F-RCCH. In this example, no additional grant is transmitted. An ACK_RC is transmitted, and a rate control command is issued (it may indicate an increase, decrease, or hold, as determined according to the desired scheduling). The mobile station then transmits the first subpacket of the next packet, using parameters associated with the grant, modified as necessary by the rate control command on the F-RCCH.

[00182] FIG. 11 depicts timing for an example embodiment with combined acknowledgement and rate control channels, along with a new grant. A request, grant, subpacket transmission (not decoded correctly) and NAK are transmitted the same as the first eight frames described above with respect to FIG. 10. In this example, the second subpacket transmission is also received and decoded correctly. However, instead of an ACK_RC being sent by the base station, an ACK_STOP is transmitted. If no grant accompanied the ACK_STOP, the mobile station would revert to autonomous transmission. Instead, a new grant is transmitted. The mobile station needn't monitor the F-RCCH for this frame. The mobile station then transmits the first subpacket of the next packet in accordance with the new grant.

[00183] FIG. 12 depicts timing for an example embodiment with combined acknowledgement and rate control channels, without a grant. This example is identical to FIG. 10, except that no grant is sent in response to the original mobile station request. Thus, the first subpacket transmission of the first packet is transmitted at the autonomous rate. Again, this subpacket is decoded incorrectly at the base station. The second subpacket is again decoded correctly, and an ACK_RC is transmitted along with a rate control command. The mobile station then sends the next packet at the potentially adjusted rate. This example illustrates the possibility of moving a mobile station rate arbitrarily using rate control commands only, without any grant.

[00184] Note that in an alternative embodiment, a base station may use rate control with autonomous transmissions with or without a previous request. Reductions may be used to relieve congestion, and an increase may be awarded when there is extra capacity, even though the BS may not know the data requirements, since a request was not transmitted.

[00185] It should be noted that in all the embodiments described above, method steps can be interchanged without departing from the scope of the invention. The descriptions disclosed herein have in many cases referred to signals, parameters, and procedures associated with a 1xEV-DV system, but the scope of the present invention is not limited as such. Those of skill in the art will readily apply the principles herein to various other communication systems. These and other modifications will be apparent to those of ordinary skill in the art.

[00186] Those of skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[00187] Those of skill would further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular

application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

[00188] The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[00189] The steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

[00190] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

[00191] **WHAT IS CLAIMED IS:**

CLAIMS

1. An apparatus, comprising:
a message generator for:
generating a first message comprising an acknowledgment indicator and a rate control indicator; and
generating a second message conditioned on the rate control indicator.

2. The apparatus of claim 1, wherein the second message comprises a rate control command.

3. The apparatus of claim 2, wherein the rate control command is one of a plurality of values, wherein one or more of the plurality of values indicates a rate increase.

4. The apparatus of claim 2, wherein the rate control command is one of a plurality of values, wherein one or more of the plurality of values indicates a rate decrease.

5. The apparatus of claim 2, wherein the rate control command is one of a plurality of values, wherein one or more of the plurality of values indicates a rate hold.

6. An apparatus, comprising:
a receiver for receiving a packet;
a decoder for decoding the received packet; and
a message generator for:
generating a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and
conditionally generating a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first signal indicates a rate control command.

7. The apparatus of claim 6, further comprising a transmitter for transmitting the first signal conditionally transmitting the second signal.

8. The apparatus of claim 6, wherein the receiver is further operable to receive one or more transmission requests and one or more autonomous transmissions, the apparatus further comprising a scheduler for allocating a shared resource in response to the one or more transmission requests and the one or more autonomous transmissions.

9. The apparatus of claim 8, wherein the message generator further generates a grant message in response to a transmission request in accordance with the allocation.

10. An apparatus, comprising:

a receiver for receiving a first signal and conditionally receiving a second signal in accordance with a rate control indicator; and

a message decoder for decoding the rate control indicator from the received first signal.

11. The apparatus of claim 10, wherein the first signal comprises an acknowledgement.

12. The apparatus of claim 10, wherein the second signal comprises a rate control command.

13. The apparatus of claim 12, wherein the rate control command is one of a plurality of values, wherein one or more of the plurality of values indicates a rate increase.

14. The apparatus of claim 12, wherein the rate control command is one of a plurality of values, wherein one or more of the plurality of values indicates a rate decrease.

15. The apparatus of claim 12, wherein the rate control command is one of a plurality of values, wherein one or more of the plurality of values indicates a rate hold.

16. The apparatus of claim 10, further comprising a transmitter for transmitting a packet.

17. The apparatus of claim 16, wherein the transmitter retransmits the packet when the first signal indicates the transmitted packet is not acknowledged.

18. The apparatus of claim 16, wherein the second signal comprises a rate control command, and the transmitter transmits a second packet at a rate determined in accordance with a rate control command.

19. A base station, comprising:

a message generator for:

generating a first message comprising an acknowledgment indicator and a rate control indicator; and

generating a second message conditioned on the rate control indicator.

20. A remote station, comprising:

a receiver for receiving a first signal and conditionally receiving a second signal in accordance with a rate control indicator; and

a message decoder for decoding the rate control indicator from the received first signal.

21. A wireless communication system, including a base station, comprising:

a message generator for:

generating a first message comprising an acknowledgment indicator and a rate control indicator; and

generating a second message conditioned on the rate control indicator.

22. A wireless communication system, including a remote station, comprising:

a receiver for receiving a first signal and conditionally receiving a second signal in accordance with a rate control indicator; and

a message decoder for decoding the rate control indicator from the received first signal.

23. A method for rate control, comprising:

generating a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and

conditionally generating a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first signal indicates a rate control command.

24. A method for rate control, comprising:

receiving a packet;

decoding the packet;

generating a first signal indicating whether the received packet was decoded correctly and indicating whether a rate control command will be issued; and

generating a second signal comprising the rate control command when a rate control command is issued.

25. The method of claim 24, wherein the first signal comprises one of a first plurality of values, one of the first plurality of values indicating an acknowledgment of correct decoding and no rate control command.

26. The method of claim 25, wherein the value indicating an acknowledgment of correct decoding and no rate control command revokes a prior grant.

27. The method of claim 24, wherein the first signal comprises one of a first plurality of values, one of the first plurality of values indicating an acknowledgment of correct decoding and a rate control command.

28. The method of claim 24, wherein the first signal comprises a value indicating no transmission corresponding to a negative acknowledgment of the decoded packet and no rate control command.

29. The method of claim 24, wherein the rate control command is one of a second plurality of values, wherein one or more of the second plurality of values indicates a rate increase.

30. The method of claim 24, wherein the rate control command is one of a second plurality of values, wherein one or more of the second plurality of values indicates a rate decrease.

31. The method of claim 24, wherein the rate control command is one of a second plurality of values, wherein one of the second plurality of values indicates a rate hold.

32. The method of claim 31, wherein the second signal comprises a value indicating no transmission for a rate hold.

33. The method of claim 24, further comprising:

receiving one or more transmission requests;

receiving one or more autonomous transmissions; and

allocating a shared resource in response to the one or more transmission requests and the one or more autonomous transmissions.

34. The method of claim 24, further comprising generating a grant in response to a received transmission request.

35. The method of claim 34, wherein the second signal is not generated when a grant is generated.

36. The method of claim 24, further comprising:

transmitting the first signal; and

conditionally transmitting the second signal when a rate control command is issued.

37. The method of claim 36, further comprising transmitting the grant when a grant is issued.

38. The method of claim 24, wherein the received packet is a subpacket.

39. The method of claim 39, wherein the decoding is performed in response to previously received corresponding subpackets, if any.

40. A method for rate control, comprising:

receiving a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and

conditionally receiving a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first received signal indicates a rate control command.

41. A method for rate control, comprising:

transmitting a packet;

receiving a first signal indicating whether the transmitted packet was acknowledged and whether a rate control command will be issued; and

receiving a second signal comprising the rate control command when a rate control command is issued.

42. The method of claim 41, wherein the first signal comprises one of a first plurality of values, one of the first plurality of values indicating an acknowledgment of correct decoding and no rate control command.

43. The method of claim 42, wherein the value indicating an acknowledgment of correct decoding and no rate control command revokes a prior grant.

44. The method of claim 41, wherein the first signal comprises one of a first plurality of values, one of the first plurality of values indicating an acknowledgment of correct decoding and a rate control command.

45. The method of claim 41, wherein the first signal comprises a value indicating no transmission corresponding to a negative acknowledgment of the decoded packet and no rate control command.

46. The method of claim 41, wherein the rate control command is one of a second plurality of values, wherein one or more of the second plurality of values indicates a rate increase.

47. The method of claim 41, wherein the rate control command is one of a second plurality of values, wherein one or more of the second plurality of values indicates a rate decrease.

48. The method of claim 41, wherein the rate control command is one of a second plurality of values, wherein one of the second plurality of values indicates a rate hold.

49. The method of claim 48, wherein the second signal comprises a value indicating no transmission for a rate hold.

50. The method of claim 41, further comprising:

retransmitting the packet when the first received signal indicates the transmitted packet was not acknowledged.

51. The method of claim 41, further comprising:

transmitting a second packet when the first received signal indicates the transmitted packet was acknowledged.

52. The method of claim 41, wherein the second packet is transmitted at a rate determined in accordance with the rate control command when a rate control command is received on the second signal.

53. The method of claim 41, wherein the transmitted packet is a subpacket.

54. An apparatus, comprising:

means for generating a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and

means for conditionally generating a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first signal indicates a rate control command.

55. A method for rate control, comprising:

means for receiving a packet;

means for decoding the packet;

means for generating a first signal indicating whether the received packet was decoded correctly and indicating whether a rate control command will be issued; and

means for generating a second signal comprising the rate control command when a rate control command is issued.

56. A method for rate control, comprising:

means for receiving a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and

means for conditionally receiving a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first received signal indicates a rate control command.

57. A method for rate control, comprising:

means for transmitting a packet;

means for receiving a first signal indicating whether the transmitted packet was acknowledged and whether a rate control command will be issued; and

means for receiving a second signal comprising the rate control command when a rate control command is issued.

58. A wireless communication system, comprising:

means for generating a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and

means for conditionally generating a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first signal indicates a rate control command.

59. A wireless communication system, comprising:

means for receiving a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and

means for conditionally receiving a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first received signal indicates a rate control command.

60. Computer readable media operable to perform the following steps:

generating a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and

conditionally generating a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first signal indicates a rate control command.

61. Computer readable media operable to perform the following steps:

receiving a packet;

decoding the packet;

generating a first signal indicating whether the received packet was decoded correctly and indicating whether a rate control command will be issued; and

generating a second signal comprising the rate control command when a rate control command is issued.

62. Computer readable media operable to perform the following steps:

receiving a first signal comprising one of a first plurality of values, each value associated with an acknowledgment (ACK) or negative acknowledgment (NAK), and one or more of the values indicating a rate control command; and

conditionally receiving a second signal comprising one of a second plurality of values corresponding to a respective plurality of rate control commands when the value of the first received signal indicates a rate control command.

63. Computer readable media operable to perform the following steps:

transmitting a packet;

receiving a first signal indicating whether the transmitted packet was acknowledged and whether a rate control command will be issued; and

receiving a second signal comprising the rate control command when a rate control command is issued.

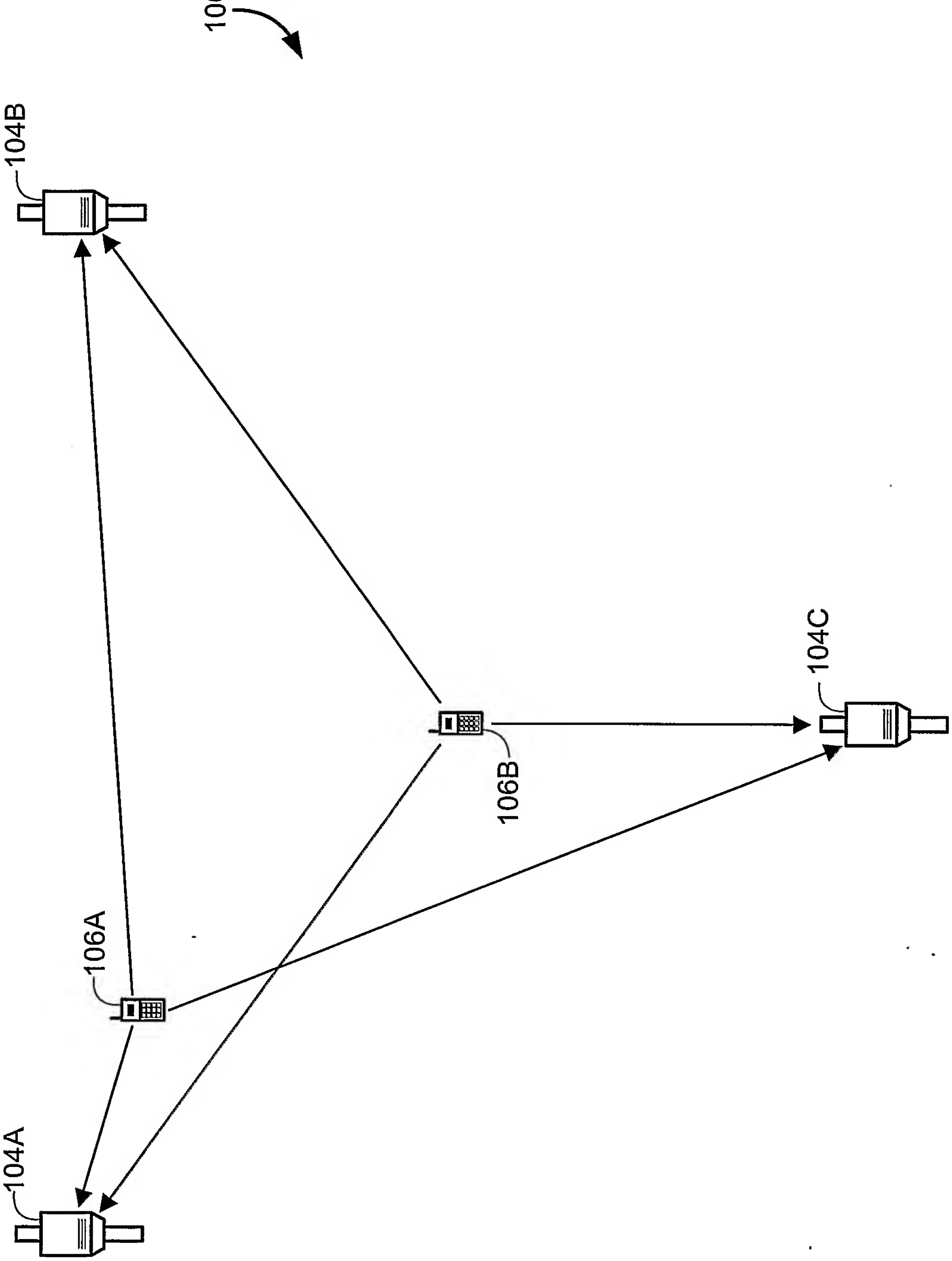


FIG. 1

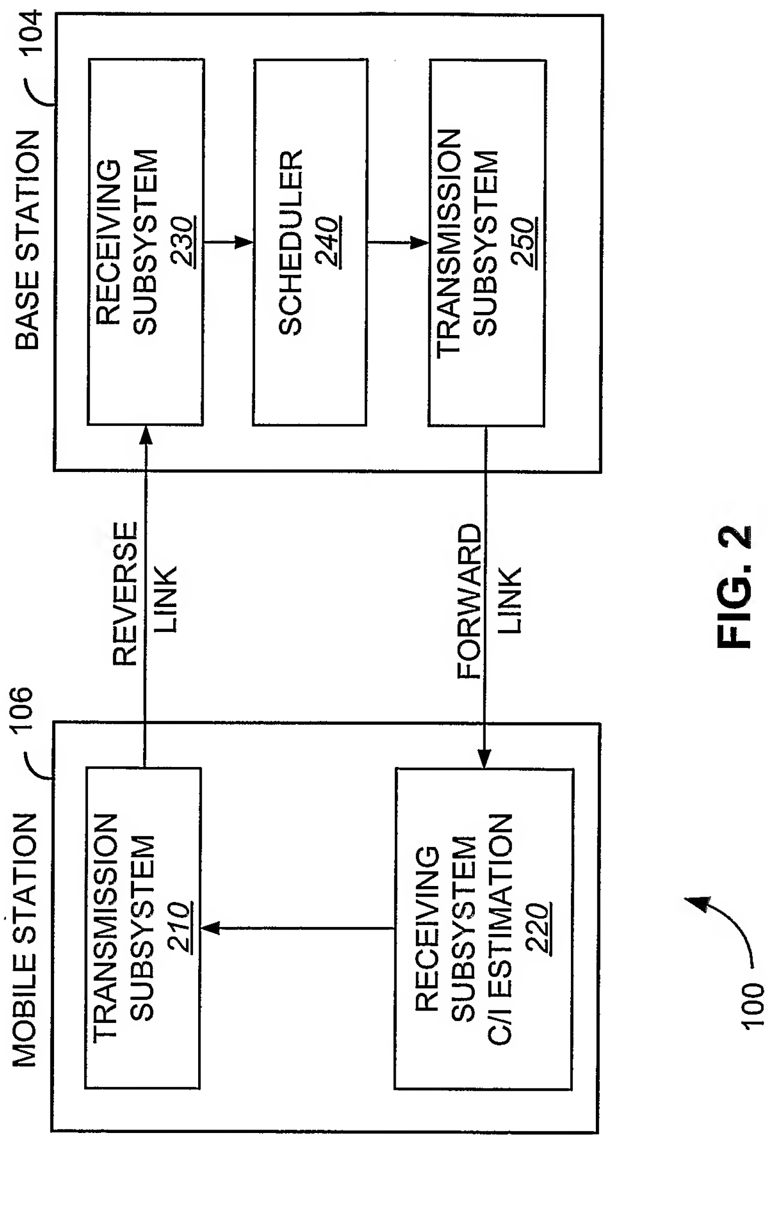

BASE STATION
104
RECEIVING SUBSYSTEM 230
SCHEDULER 240
TRANSMISSION SUBSYSTEM 250
REVERSE LINK
FORWARD LINK
MOBILE STATION
106
TRANSMISSION SUBSYSTEM 210
RECEIVING SUBSYSTEM C/I ESTIMATION 220
100

FIG. 2

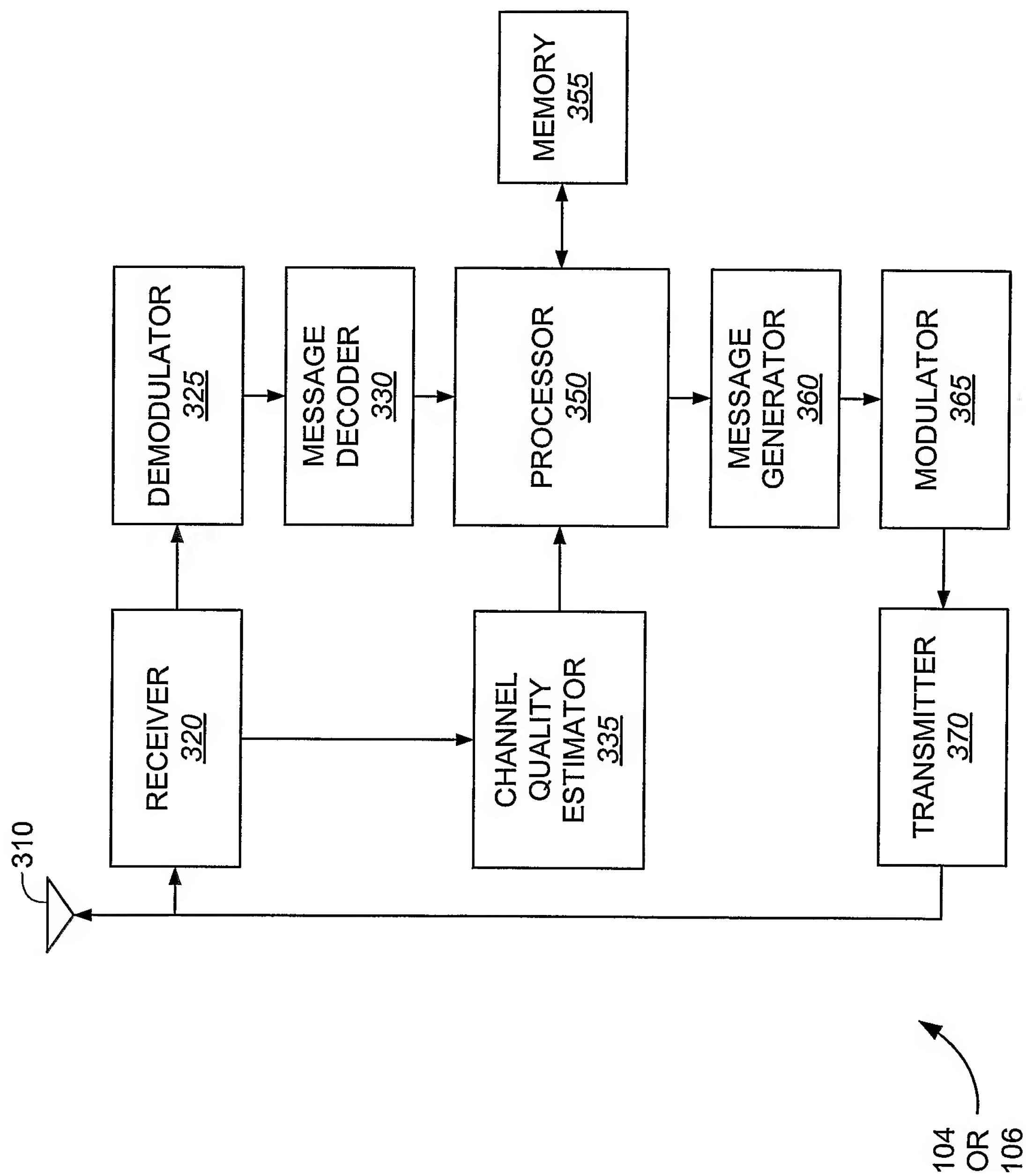

310
RECEIVER 320
DEMODULATOR 325
MESSAGE DECODER 330
CHANNEL QUALITY ESTIMATOR 335
PROCESSOR 350
MEMORY 355
MESSAGE GENERATOR 360
MODULATOR 365
TRANSMITTER 370
104 OR 106

FIG. 3

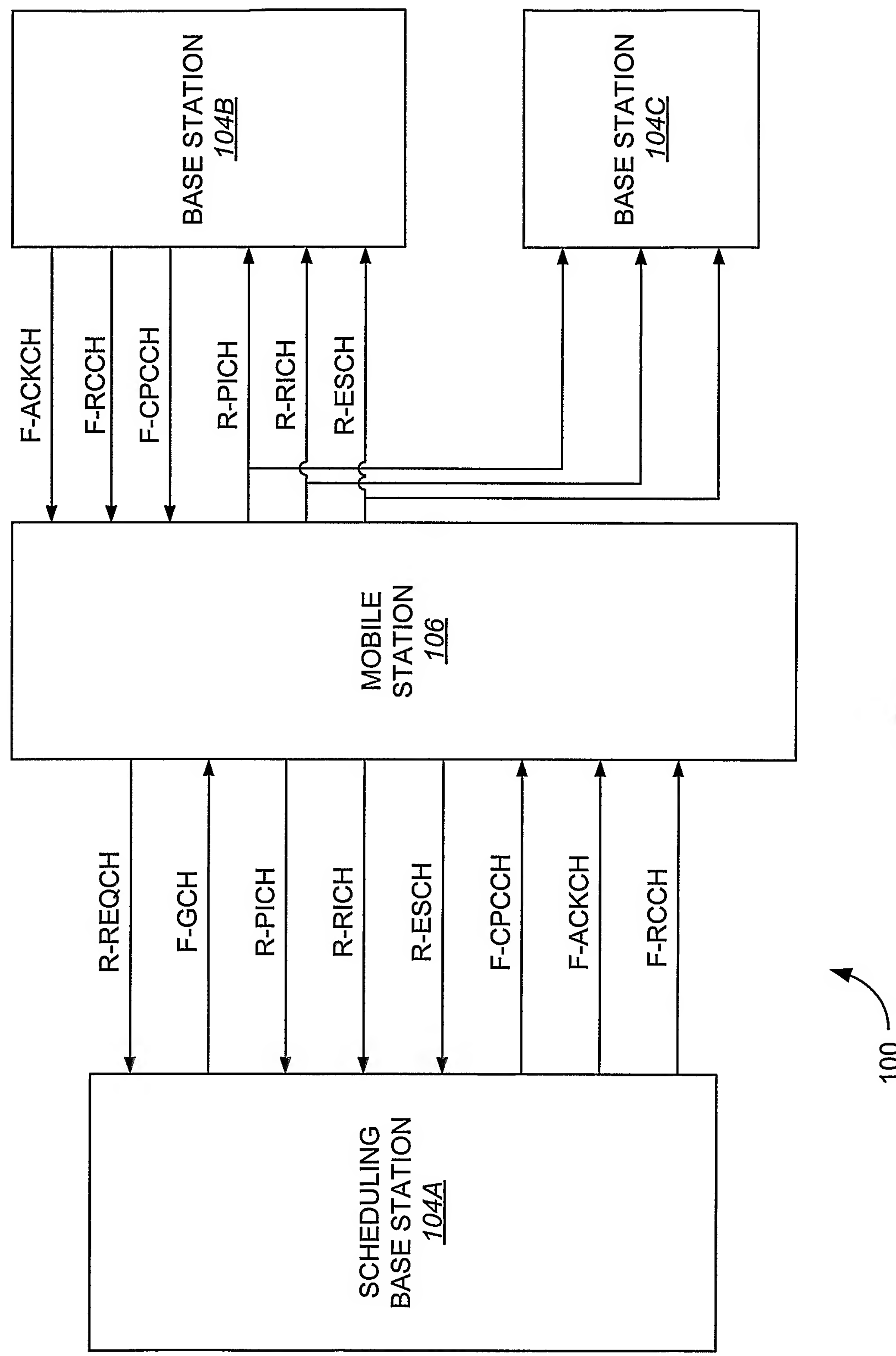

BASE STATION
104B
BASE STATION
104C
F-ACKCH
F-RCCH
F-CPCCH
R-PICH
R-RICH
R-ESCH
MOBILE
STATION
106
R-REQCH
F-GCH
R-PICH
R-RICH
R-ESCH
F-CPCCH
F-ACKCH
F-RCCH
SCHEDULING
BASE STATION
104A
100

FIG. 4

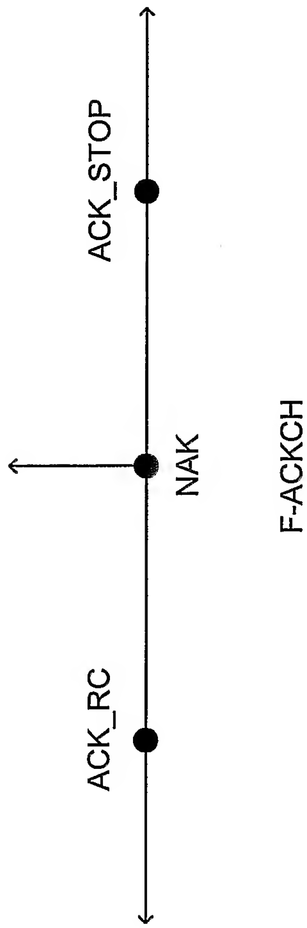

ACK_STOP
NAK
ACK_RC
F-ACKCH

FIG. 5

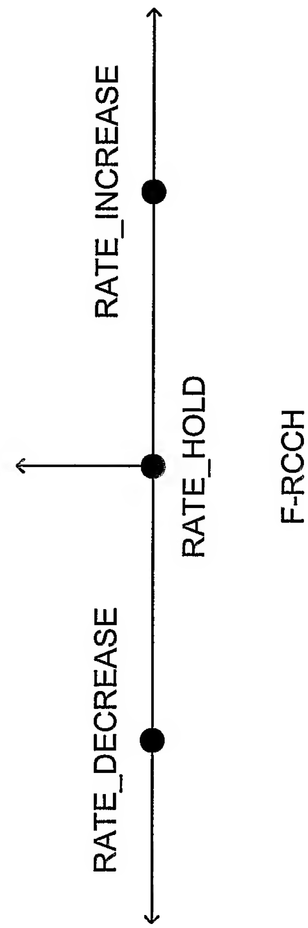

RATE_INCREASE
RATE_HOLD
RATE_DECREASE
F-RCCH

FIG. 6

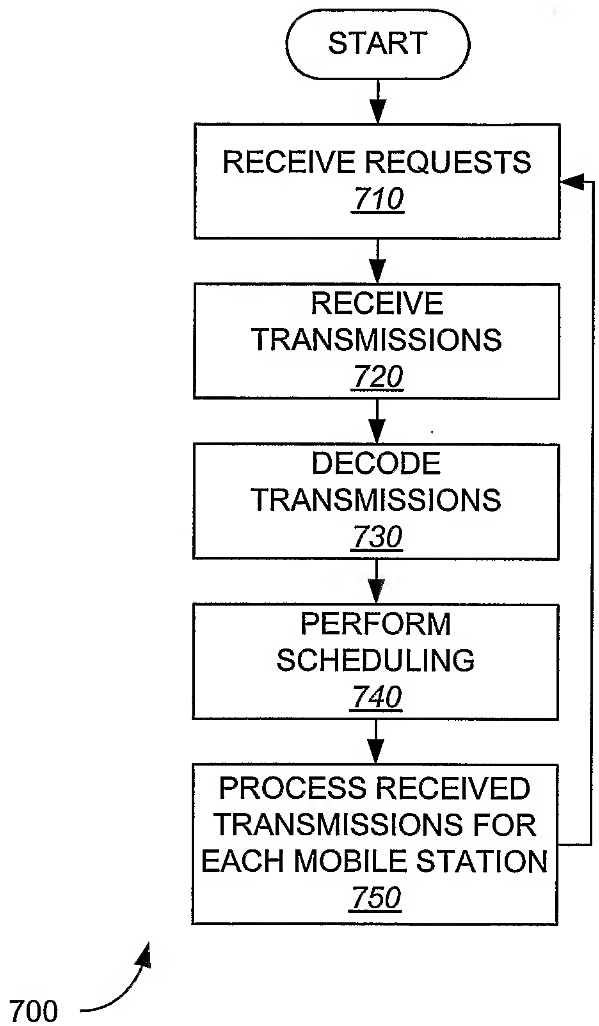

START
RECEIVE REQUESTS
710
RECEIVE TRANSMISSIONS
720
DECODE TRANSMISSIONS
730
PERFORM SCHEDULING
740
PROCESS RECEIVED TRANSMISSIONS FOR EACH MOBILE STATION
750
700

FIG. 7

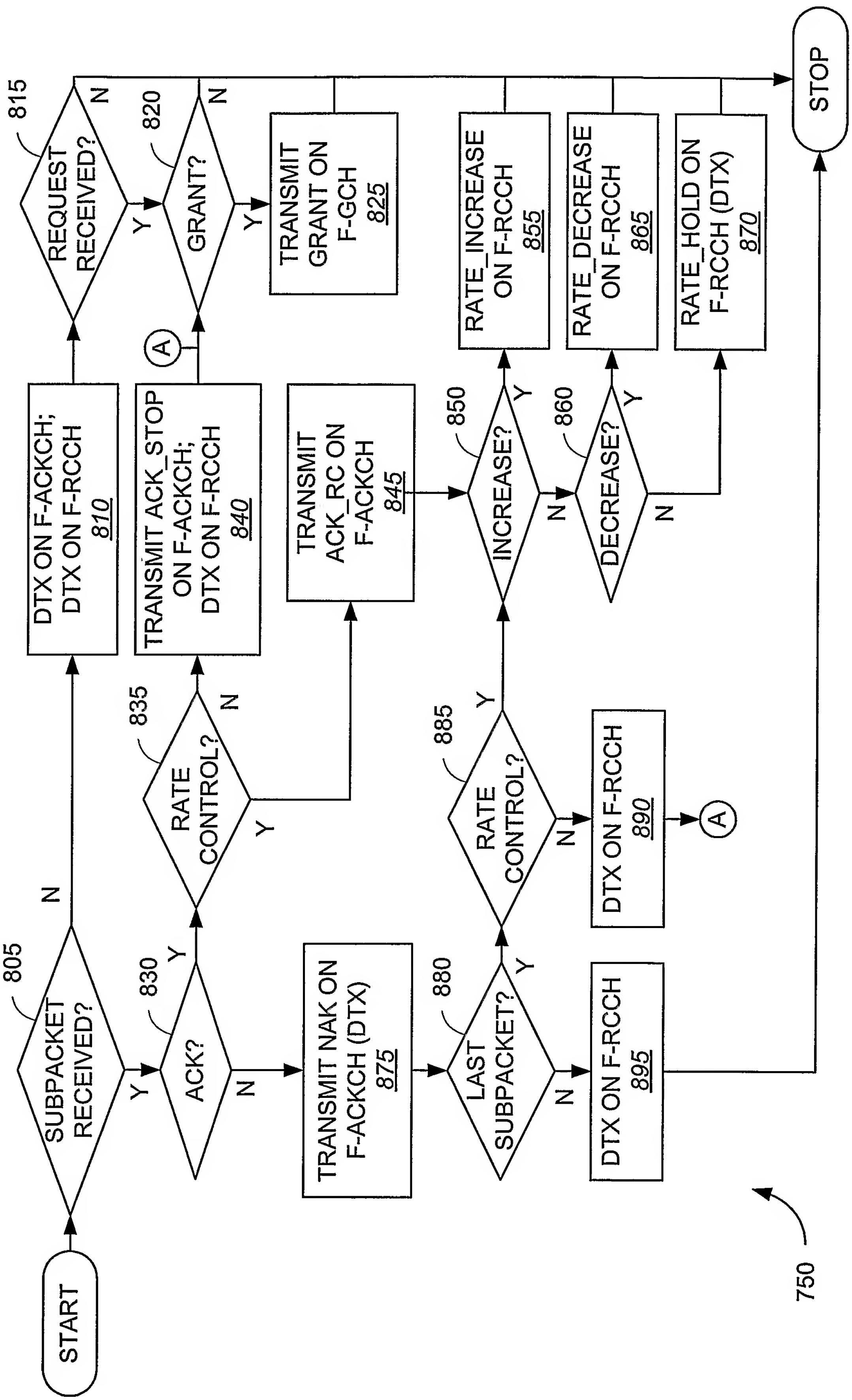

START
SUBPACKET RECEIVED?
805
Y
N
DTX ON F-ACKCH; DTX ON F-RCCH
810
REQUEST RECEIVED?
815
N
Y
GRANT?
820
N
Y
TRANSMIT GRANT ON F-GCH
825
ACK?
830
Y
N
RATE CONTROL?
835
N
Y
TRANSMIT ACK_STOP ON F-ACKCH; DTX ON F-RCCH
840
A
TRANSMIT ACK_RC ON F-ACKCH
845
INCREASE?
850
Y
N
RATE_INCREASE ON F-RCCH
855
DECREASE?
860
Y
N
RATE_DECREASE ON F-RCCH
865
RATE_HOLD ON F-RCCH (DTX)
870
TRANSMIT NAK ON F-ACKCH (DTX)
875
LAST SUBPACKET?
880
Y
N
RATE CONTROL?
885
Y
N
DTX ON F-RCCH
890
A
DTX ON F-RCCH
895
STOP
750

FIG. 8

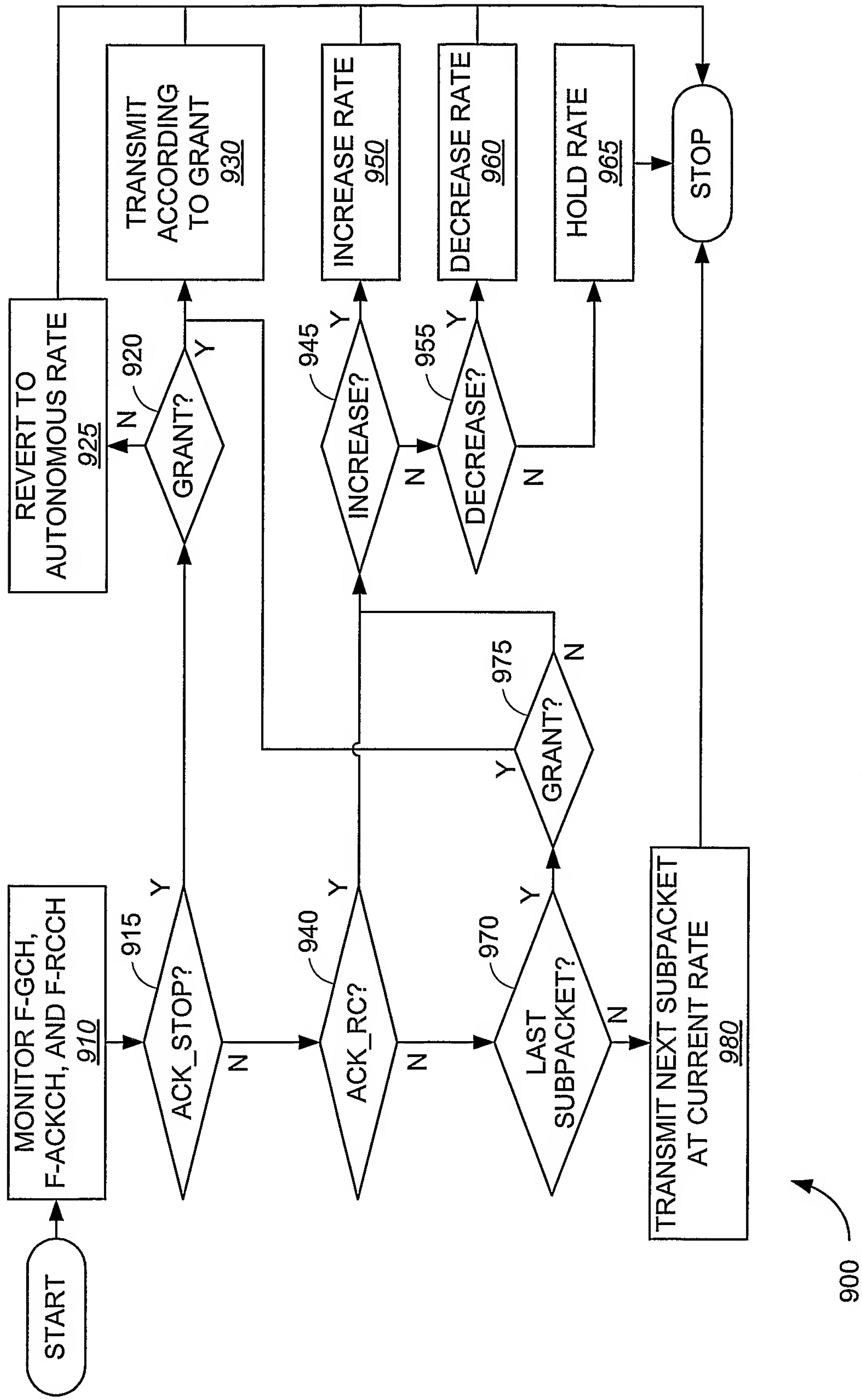

START
MONITOR F-GCH, F-ACKCH, AND F-RCCH 910
915
ACK_STOP?
Y
N
920
GRANT?
Y
N
REVERT TO AUTONOMOUS RATE 925
TRANSMIT ACCORDING TO GRANT 930
940
ACK_RC?
Y
N
945
INCREASE?
Y
N
INCREASE RATE 950
955
DECREASE?
Y
N
DECREASE RATE 960
HOLD RATE 965
970
LAST SUBPACKET?
Y
N
975
GRANT?
Y
N
TRANSMIT NEXT SUBPACKET AT CURRENT RATE 980
STOP
900

FIG. 9

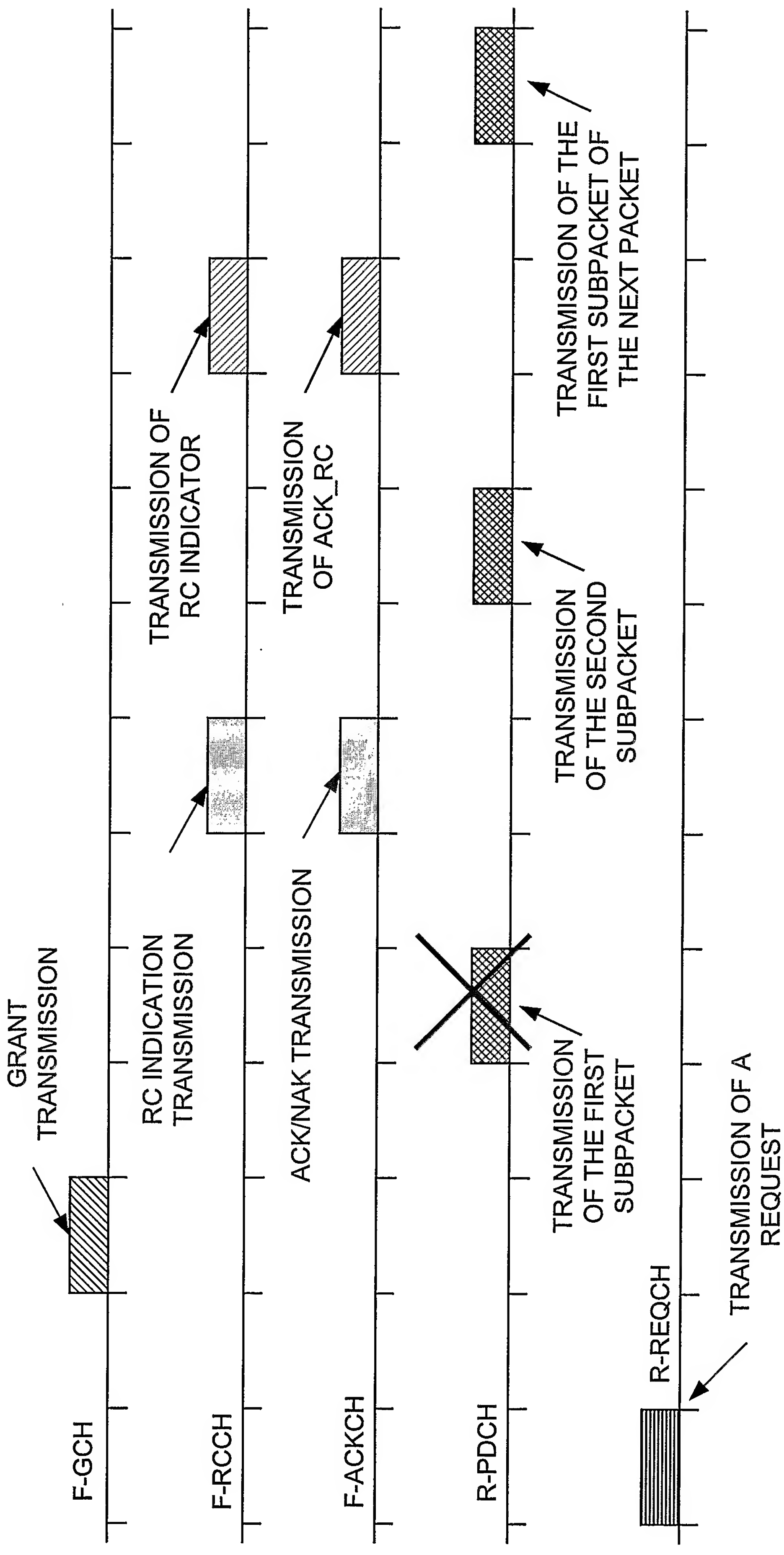
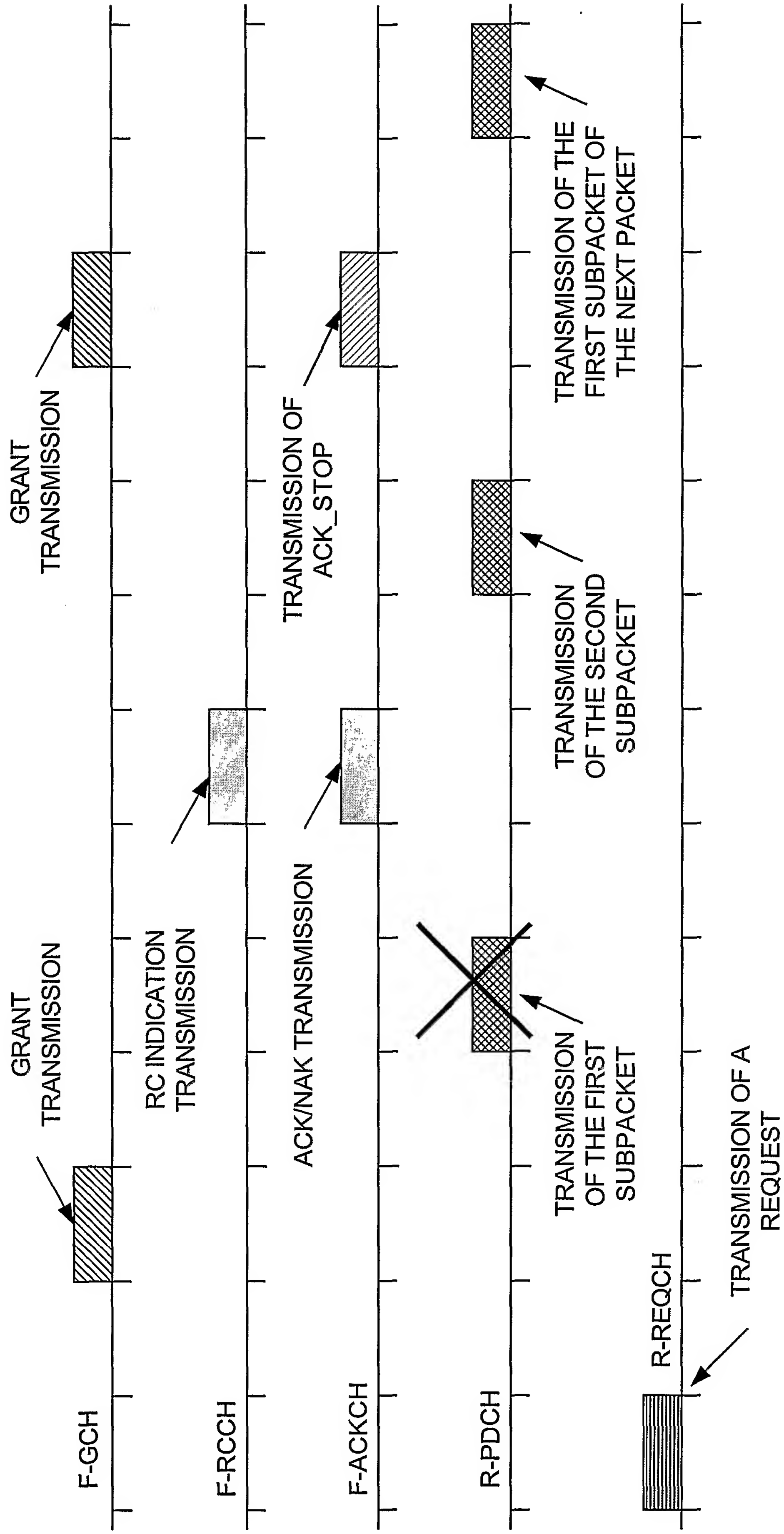
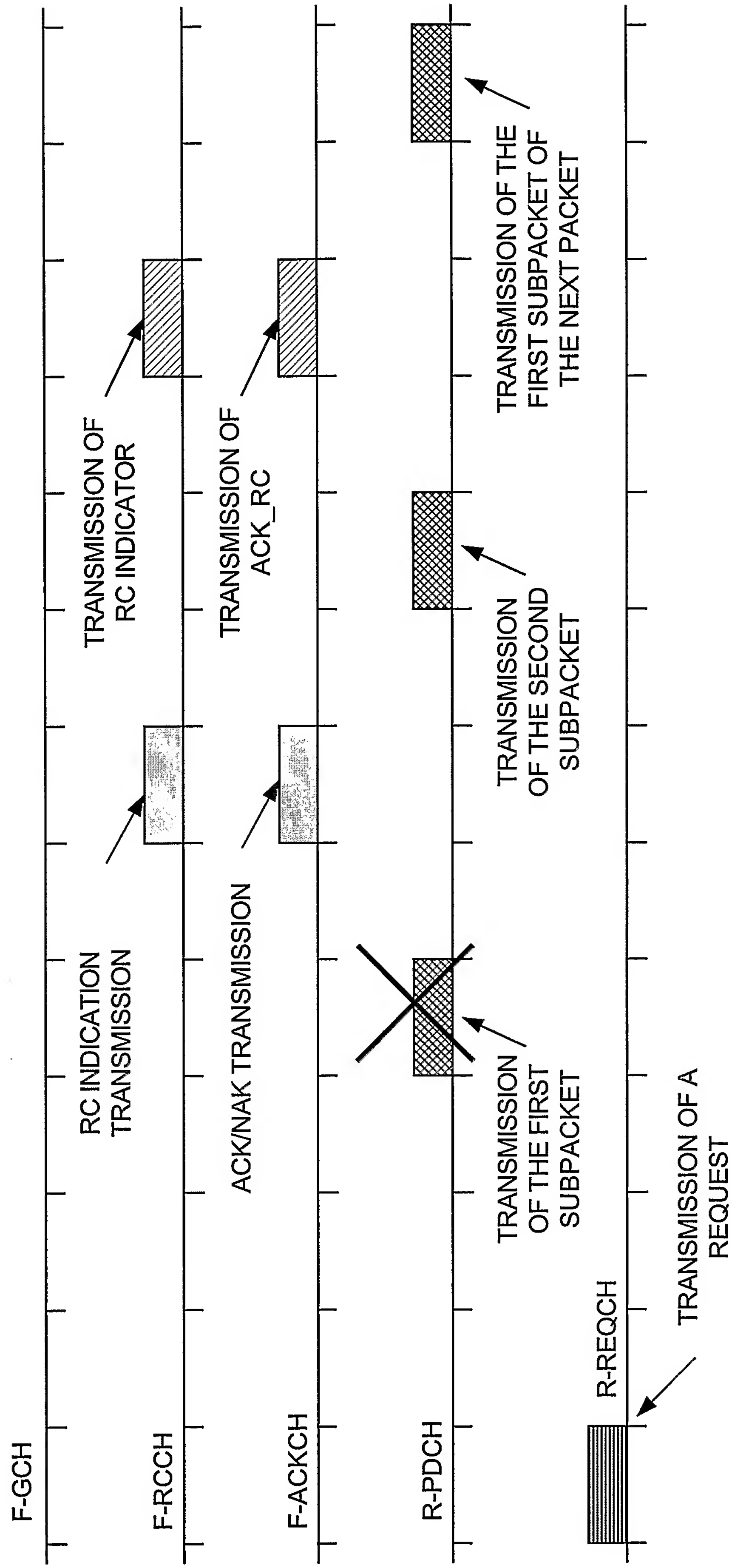

F-GCH
F-RCCH
F-ACKCH
R-PDCH
R-REQCH
GRANT TRANSMISSION
RC INDICATION TRANSMISSION
ACK/NAK TRANSMISSION
TRANSMISSION OF THE FIRST SUBPACKET
TRANSMISSION OF A REQUEST
TRANSMISSION OF RC INDICATOR
TRANSMISSION OF ACK_RC
TRANSMISSION OF THE SECOND SUBPACKET
TRANSMISSION OF THE FIRST SUBPACKET OF THE NEXT PACKET

FIG. 10



F-GCH
F-RCCH
F-ACKCH
R-PDCH
R-REQCH
GRANT TRANSMISSION
RC INDICATION TRANSMISSION
ACK/NAK TRANSMISSION
TRANSMISSION OF THE FIRST SUBPACKET
TRANSMISSION OF A REQUEST
TRANSMISSION OF THE SECOND SUBPACKET
GRANT TRANSMISSION
TRANSMISSION OF ACK_STOP
TRANSMISSION OF THE FIRST SUBPACKET OF THE NEXT PACKET

FIG. 11



F-GCH
F-RCCH
F-ACKCH
R-PDCH
R-REQCH
TRANSMISSION OF A REQUEST
RC INDICATION TRANSMISSION
ACK/NAK TRANSMISSION
TRANSMISSION OF THE FIRST SUBPACKET
TRANSMISSION OF RC INDICATOR
TRANSMISSION OF ACK_RC
TRANSMISSION OF THE SECOND SUBPACKET
TRANSMISSION OF THE FIRST SUBPACKET OF THE NEXT PACKET

FIG. 12

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/025375

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/38 H04L1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	YOUNG-JOO SONG ET AL: "Rate-control snoop : a reliable transport protocol for heterogeneous networks with wired and wireless links" IEEE PROCEEDINGS 2003, vol. 2, 16 March 2003 (2003-03-16), pages 1334-1338, XP010639961 the whole document	1-63
A	US 2002/150077 A1 (TEMERINAC MIODRAG) 17 October 2002 (2002-10-17) abstract paragraph ‘0024! - paragraph ‘0025!	1-63

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 December 2004	22/12/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Hultsch, W

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/025375

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	NANDAGOPAL T ET AL: "Service differentiation through end-to-end rate control in low bandwidth wireless packet networks" MOBILE MULTIMEDIA COMMUNICATIONS, 1999. (MOMUC '99). 1999 IEEE INTERNATIONAL WORKSHOP ON SAN DIEGO, CA, USA 15-17 NOV. 1999, PISCATAWAY, NJ, USA,IEEE, US, 15 November 1999 (1999-11-15), pages 211-220, XP010370726 ISBN: 0-7803-5904-6 the whole document -----	1-63
A	US 6 425 105 B1 (PIIRAINEN OLLI ET AL) 23 July 2002 (2002-07-23) column 1, line 8 - column 5, line 28; figure 2 -----	1-63

International Application No
PCT/US2004/025375

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2002150077	A1	17-10-2002	EP	1176778	A1	30-01-2002
			JP	2002111778	A	12-04-2002
US 6425105	B1	23-07-2002	WO	0013364	A1	09-03-2000
			AU	9265298	A	21-03-2000
			EP	1025666	A1	09-08-2000
			JP	2002524918	T	06-08-2002
			NO	20002095	A	25-04-2000

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(19) World Intellectual Property Organization
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22 August 2002 (22.08.2002)

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(10) International Publication Number
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(51) International Patent Classification[7]: H04B 7/00

(21) International Application Number: PCT/US02/05171

(22) International Filing Date: 14 February 2002 (14.02.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
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(72) Inventors: **TIEDEMANN, Edward, G., Jr.**; 656 Barretts Mill Road, Concord, MA 01742 (US). **CHEN, Tao**; 5415 Harvest Run Drive, San Diego, CA 92130 (US). **JAIN, Avinash**; 11143 Caminito Alvarez, San Diego, CA 92126 (US).

(74) Agents: **WADSWORTH, Philip, R.** et al.; Qualcomm Incorporated, 5775 Morehouse Drive, San Diego, CA 92121-1714 (US).

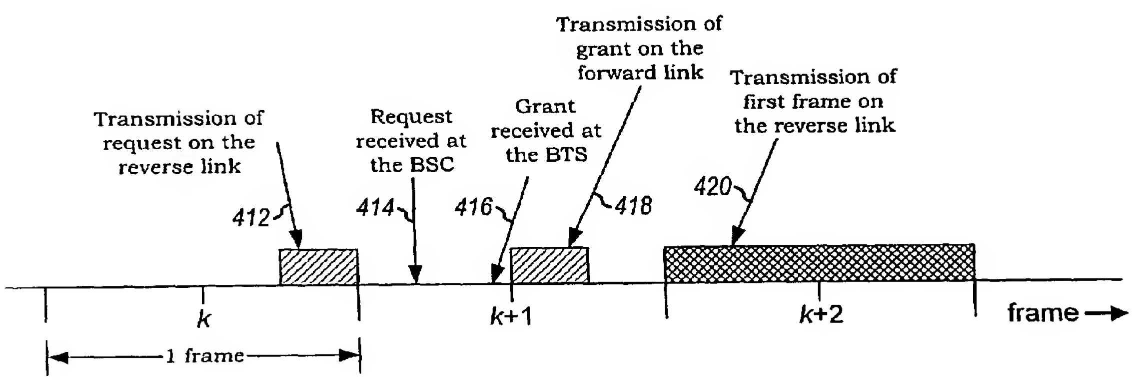
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: REVERSE LINK CHANNEL ARCHITECTURE FOR A WIRELESS COMMUNICATION SYSTEM



(57) Abstract: A channel structure and mechanisms that support effective and efficient allocation and utilization of the reverse link resources. In one aspect, mechanisms are provided to quickly assign resources (e.g., a supplemental channel) as needed, and to quickly de-assign the resources when not needed or to maintain system stability. The reverse link resources may be quickly assigned and de-assigned via short messages (412, 418) exchanged on control channels on the forward and reverse links. In another aspect, mechanisms are provided to facilitate efficient and reliable data transmission. A reliable acknowledgment/negative acknowledgment scheme and an efficient retransmission scheme are provided. Mechanisms are also provided to control the transmit power and/or data rate of the remote terminals to achieve high performance and avoid instability.

WO 02/065664 A2

REVERSE LINK CHANNEL ARCHITECTURE FOR A WIRELESS COMMUNICATION SYSTEM

BACKGROUND

Field

[1001] The present invention relates generally to data communication, and more specifically to a novel and improved reverse link architecture for a wireless communication system.

Background

[1002] Wireless communication systems are widely deployed to provide various types of communication including voice and packet data services. These systems may be based on code division multiple access (CDMA), time division multiple access (TDMA), or some other modulation techniques. CDMA systems may provide certain advantages over other types of system, including increased system capacity.

[1003] In a wireless communication system, a user with a remote terminal (e.g., a cellular phone) communicates with another user through transmissions on the forward and reverse links via one or more base stations. The forward link (i.e., downlink) refers to transmission from the base station to the user terminal, and the reverse link (i.e., uplink) refers to transmission from the user terminal to the base station. The forward and reverse links are typically allocated different frequencies, a method called frequency division multiplexing (FDM).

[1004] The characteristics of packet data transmission on the forward and reverse links are typically very different. On the forward link, the base station usually knows whether or not it has data to transmit, the amount of data, and the identity of the recipient remote terminals. The base station may further be provided with the "efficiency" achieved by each recipient remote terminal, which may be quantified as the amount of transmit power needed per bit. Based on the known information, the base station may be able to efficiently schedule data

transmissions to the remote terminals at the times and data rates selected to achieve the desired performance.

[1005] On the reverse link, the base station typically does not know *a priori* which remote terminals have packet data to transmit, or how much. The base station is typically aware of each received remote terminal's efficiency, which may be quantified by the energy-per-bit-to-total-noise-plus-interface ratio, Ec/(No+Io), needed at the base station to correctly receive a data transmission. The base station may then allocate resources to the remote terminals whenever requested and as available.

[1006] Because of uncertainty in user demands, the usage on the reverse link may fluctuate widely. If many remote terminals transmit at the same time, high interference is generated at the base station. The transmit power from the remote terminals would need to be increased to maintain the target Ec/(No+Io), which would then result in higher levels of interference. If the transmit power is further increased in this manner, a "black out" may ultimately result and the transmissions from all or a large percentage of the remote terminals may not be properly received. This is due to the remote terminal not being able to transmit at sufficient power to close the link to the base station.

[1007] In a CDMA system, the channel loading on the reverse link is often characterized by what is referred to as the "rise-over-thermal". The rise-over-thermal is the ratio of the total received power at a base station receiver to the power of the thermal noise. Based on theoretical capacity calculations for a CDMA reverse link, there is a theoretical curve that shows the rise-over-thermal increasing with loading. The loading at which the rise-over-thermal is infinite is often referred to as the "pole". A loading that has a rise-over-thermal of 3 dB corresponds to a loading of about 50%, or about half of the number of users that can be supported when at the pole. As the number of users increases and as the data rates of the users increase, the loading becomes higher. Correspondingly, as the loading increases, the amount of power that a remote terminal must transmit increases. The rise-over-thermal and channel loading are described in further detail by A.J. Viterbi in "CDMA : Principles of Spread Spectrum Communication," Addison-Wesley Wireless Communications Series, May 1995, ISBN: 0201633744, which is incorporated herein by reference.

[1008] The Viterbi reference provides classical equations that show the relationship between the rise-over-thermal, the number of users, and the data rates of the users. The equations also show that there is greater capacity (in bits/second) if a few users transmit at a high rate than a larger number of users transmit at a higher rate. This is due to the interference between transmitting users.

[1009] In a typical CDMA system, many users' data rates are continuously changing. For example, in an IS-95 or cdma2000 system, a voice user typically transmits at one of four rates, corresponding to the voice activity at the remote terminal, as described in U.S Patent Nos. 5,657,420 and 5,778,338, both entitled "VARIABLE RATE VOCODER" and U.S Patent No. 5,742,734, entitled "ENCODING RATE SELECTION IN A VARIABLE RATE VOCODER". Similarly, many data users are continually varying their data rates. All this creates a considerable amount of variation in the amount of data being transmitted simultaneously, and hence a considerable variation in the rise-over-thermal.

[1010] As can be seen from the above, there is a need in the art for a reverse link channel structure capable of achieving high performance for packet data transmission, and which takes into consideration the data transmission characteristics of the reverse links.

SUMMARY

[1011] Aspects of the invention provide mechanisms that support effective and efficient allocation and utilization of the reverse link resources. In one aspect, mechanisms are provided to quickly assign resources (e.g., supplemental channels) as needed, and to quickly de-assign the resources when not needed or to maintain system stability. The reverse link resources may be quickly assigned and de-assigned via short messages exchanged on control channels on the forward and reverse links. In another aspect, mechanisms are provided to facilitate efficient and reliable data transmission. In particular, a reliable acknowledgment/negative acknowledgment scheme and an efficient retransmission scheme are provided. In yet another aspect,

mechanisms are provided to control the transmit power and/or data rate of the remote terminals to achieve high performance and avoid instability. Another aspect of the invention provides a channel structure capable of implementing the features described above. These and other aspects are described in further detail below.

[1012] The disclosed embodiments further provide methods, channel structures, and apparatus that implement various aspects, embodiments, and features of the invention, as described in further detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[1013] The features, nature, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

[1014] FIG. 1 is a diagram of a wireless communication system that supports a number of users;

[1015] FIG. 2 is a simplified block diagram of an embodiment of a base station and a remote terminal;

[1016] FIGS. 3A and 3B are diagrams of a reverse and a forward channel structure, respectively;

[1017] FIG. 4 is a diagram illustrating a communication between the remote terminal and base station to assign a reverse link supplemental channel (R-SCH);

[1018] FIGS. 5A and 5B are diagrams illustrating a data transmission on the reverse link and an Ack/Nak message transmission for two different scenarios;

[1019] FIGS. 6A and 6B are diagrams illustrating an acknowledgment sequencing with short and long acknowledgment delays, respectively;

[1020] FIG. 7 is a flow diagram that illustrates a variable rate data transmission on the R-SCH with fast congestion control, in accordance with an embodiment of the invention; and

[1021] FIG. 8 is a diagram illustrating improvement that may be possible with fast control of the R-SCH.

DETAILED DESCRIPTION

[1022] FIG. 1 is a diagram of a wireless communication system 100 that supports a number of users and capable of implementing various aspects of the invention. System 100 provides communication for a number of cells, with each cell being serviced by a corresponding base station 104. The base stations are also commonly referred to as base transceiver systems (BTSs). Various remote terminals 106 are dispersed throughout the system. Each remote terminal 106 may communicate with one or more base stations 104 on the forward and reverse links at any particular moment, depending on whether or not the remote terminal is active and whether or not it is in soft handoff. The forward link refers to transmission from base station 104 to remote terminal 106, and the reverse link refers to transmission from remote terminal 106 to base station 104. As shown in FIG. 1, base station 104a communicates with remote terminals 106a, 106b, 106c, and 106d, and base station 104b communicates with remote terminals 106d, 106e, and 106f. Remote terminal 106d is in soft handoff and concurrently communicates with base stations 104a and 104b.

[1023] In system 100, a base station controller (BSC) 102 couples to base stations 104 and may further couple to a public switched telephone network (PSTN). The coupling to the PSTN is typically achieved via a mobile switching center (MSC), which is not shown in FIG. 1 for simplicity. The BSC may also couple into a packet network, which is typically achieved via a packet data serving node (PDSN) that is also not shown in FIG. 1. BSC 102 provides coordination and control for the base stations coupled to it. BSC 102 further controls the routing of telephone calls among remote terminals 106, and between remote terminals 106 and users coupled to the PSTN (e.g., conventional telephones) and to the packet network, via base stations 104.

[1024] System 100 may be designed to support one or more CDMA standards such as (1) the "TIA/EIA-95-B Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" (the IS-95 standard), (2) the "TIA/EIA-98-D Recommended Minimum Standard for Dual-Mode Wideband Spread Spectrum Cellular Mobile Station"

(the IS-98 standard), (3) the documents offered by a consortium named "3rd Generation Partnership Project" (3GPP) and embodied in a set of documents including Document Nos. 3G TS 25.211, 3G TS 25.212, 3G TS 25.213, and 3G TS 25.214 (the W-CDMA standard), (4) the documents offered by a consortium named "3rd Generation Partnership Project 2" (3GPP2) and embodied in a set of documents including Document Nos. C.S0002-A, C.S0005-A, C.S0010-A, C.S0011-A. C.S0024, and C.S0026 (the cdma2000 standard), and (5) some other standards. In the case of the 3GPP and 3GPP2 documents, these are converted by standards bodies worldwide (e.g., TIA, ETSI, ARIB, TTA, and CWTS) into regional standards and have been converted into international standards by the International Telecommunications Union (ITU). These standards are incorporated herein by reference.

[1025] FIG. 2 is a simplified block diagram of an embodiment of base station 104 and remote terminal 106, which are capable of implementing various aspects of the invention. For a particular communication, voice data, packet data, and/or messages may be exchanged between base station 104 and remote terminal 106. Various types of messages may be transmitted such as messages used to establish a communication session between the base station and remote terminal and messages used to control a data transmission (e.g., power control, data rate information, acknowledgment, and so on). Some of these message types are described in further detail below.

[1026] For the reverse link, at remote terminal 106, voice and/or packet data (e.g., from a data source 210) and messages (e.g., from a controller 230) are provided to a transmit (TX) data processor 212, which formats and encodes the data and messages with one or more coding schemes to generate coded data. Each coding scheme may include any combination of cyclic redundancy check (CRC), convolutional, Turbo, block, and other coding, or no coding at all. Typically, voice data, packet data, and messages are coded using different schemes, and different types of message may also be coded differently.

[1027] The coded data is then provided to a modulator (MOD) 214 and further processed (e.g., covered, spread with short PN sequences, and scrambled with a long PN sequence assigned to the user terminal). The modulated data is then provided to a transmitter unit (TMTR) 216 and

conditioned (e.g., converted to one or more analog signals, amplified, filtered, and quadrature modulated) to generate a reverse link signal. The reverse link signal is routed through a duplexer (D) 218 and transmitted via an antenna 220 to base station 104.

[1028] At base station 104, the reverse link signal is received by an antenna 250, routed through a duplexer 252, and provided to a receiver unit (RCVR) 254. Receiver unit 254 conditions (e.g., filters, amplifies, downconverts, and digitizes) the received signal and provides samples. A demodulator (DEMOD) 256 receives and processes (e.g., despreads, decovers, and pilot demodulates) the samples to provide recovered symbols. Demodulator 256 may implement a rake receiver that processes multiple instances of the received signal and generates combined symbols. A receive (RX) data processor 258 then decodes the symbols to recover the data and messages transmitted on the reverse link. The recovered voice/packet data is provided to a data sink 260 and the recovered messages may be provided to a controller 270. The processing by demodulator 256 and RX data processor 258 are complementary to that performed at remote terminal 106. Demodulator 256 and RX data processor 258 may further be operated to process multiple transmissions received via multiple channels, e.g., a reverse fundamental channel (R-FCH) and a reverse supplemental channel (R-SCH). Also, transmissions may be received simultaneously from multiple remote terminals, each of which may be transmitting on a reverse fundamental channel, a reverse supplemental channel, or both.

[1029] On the forward link, at base station 104, voice and/or packet data (e.g., from a data source 262) and messages (e.g., from controller 270) are processed (e.g., formatted and encoded) by a transmit (TX) data processor 264, further processed (e.g., covered and spread) by a modulator (MOD) 266, and conditioned (e.g., converted to analog signals, amplified, filtered, and quadrature modulated) by a transmitter unit (TMTR) 268 to generate a forward link signal. The forward link signal is routed through duplexer 252 and transmitted via antenna 250 to remote terminal 106.

[1030] At remote terminal 106, the forward link signal is received by antenna 220, routed through duplexer 218, and provided to a receiver unit 222.

Receiver unit 222 conditions (e.g., downconverts, filters, amplifies, quadrature demodulates, and digitizes) the received signal and provides samples. The samples are processed (e.g., despreaded, decovered, and pilot demodulated) by a demodulator 224 to provide symbols, and the symbols are further processed (e.g., decoded and checked) by a receive data processor 226 to recover the data and messages transmitted on the forward link. The recovered data is provided to a data sink 228, and the recovered messages may be provided to controller 230.

[1031] The reverse link has some characteristics that are very different from those of the forward link. In particular, the data transmission characteristics, soft handoff behaviors, and fading phenomenon are typically very different between the forward and reverse links.

[1032] As noted above, on the reverse link, the base station typically does not know *a priori* which remote terminals have packet data to transmit, or how much. Thus, the base station may allocate resources to the remote terminals whenever requested and as available. Because of uncertainty in user demands, the usage on the reverse link may fluctuate widely.

[1033] In accordance with aspects of the invention, mechanisms are provided to effectively and efficiently allocate and utilize the reverse link resources. In one aspect, mechanisms are provided to quickly assign resources as needed, and to quickly de-assign resources when not needed or to maintain system stability. The reverse link resources may be assigned via a supplemental channel that is used for packet data transmission. In another aspect, mechanisms are provided to facilitate efficient and reliable data transmission. In particular, a reliable acknowledgment scheme and an efficient retransmission scheme are provided. In yet another aspect, mechanisms are provided to control the transmit power of the remote terminals to achieve high performance and avoid instability. These and other aspects are described in further detail below.

[1034] FIG. 3A is a diagram of an embodiment of a reverse channel structure capable of implementing various aspects of the invention. In this embodiment, the reverse channel structure includes an access channel, an enhanced access channel, a pilot channel (R-PICH), a common control channel (R-CCCH), a

dedicated control channel (R-DCCH), a fundamental channel (R-FCH), supplemental channels (R-SCH), and a reverse rate indicator channel (R-RICH). Different, fewer, and/or additional channels may also be supported and are within the scope of the invention. These channels may be implemented similar to those defined by the cdma2000 standard. Features of some of these channels are described below.

[1035] For each communication (i.e., each call), a specific set of channels that may be used for the communication and their configurations are defined by one of a number of radio configurations (RC). Each RC defines a specific transmission format, which is characterized by various physical layer parameters such as, for example, the transmission rates, modulation characteristics, spreading rate, and so on. The radio configurations may be similar to those defined for the cdma2000 standard.

[1036] The reverse dedicated control channel (R-DCCH) is used to transmit user and signaling information (e.g., control information) to the base station during a communication. The R-DCCH may be implemented similar to the R-DCCH defined in the cdma2000 standard.

[1037] The reverse fundamental channel (R-FCH) is used to transmit user and signaling information (e.g., voice data) to the base station during a communication. The R-FCH may be implemented similar to the R-FCH defined in the cdma2000 standard.

[1038] The reverse supplemental channel (R-SCH) is used to transmit user information (e.g., packet data) to the base station during a communication. The R-SCH is supported by some radio configurations (e.g., RC3 through RC11), and is assigned to the remote terminals as needed and if available. In an embodiment, zero, one, or two supplemental channels (i.e., R-SCH1 and R-SCH2) may be assigned to the remote terminal at any given moment. In an embodiment, the R-SCH supports retransmission at the physical layer, and may utilize different coding schemes for the retransmission. For example, a retransmission may use a code rate of 1/2 for the original transmission. The same rate 1/2 code symbols may be repeated for the retransmission. In an alternative embodiment, the underlying code may be a rate 1/4 code. The original transmission may use 1/2 of the symbols and the retransmission may

use the other half of the symbols. If a third retransmission is done, it can repeat one of the group of symbols, part of each group, a subset of either group, and other possible combinations of symbols.

[1039] R-SCH2 may be used in conjunction with R-SCH1 (e.g., for RC11). In particular, R-SCH2 may be used to provide a different quality of service (QoS). Also, Type II and III hybrid ARQ schemes may be used in conjunction with the R-SCH. Hybrid ARQ schemes are generally described by S.B. Wicker in "Error Control System for Digital Communication and Storage," Prentice-Hall, 1995, Chapter 15, which is incorporated herein by reference. Hybrid ARQ schemes are also described in the cdma2000 standard.

[1040] The reverse rate indicator channel (R-RICH) is used by the remote terminal to provide information pertaining to the (packet) transmission rate on one or more reverse supplemental channels. Table 1 lists the fields for a specific format of the R-RICH. In an embodiment, for each data frame transmission on the R-SCH, the remote terminal sends a reverse rate indicator (RRI) symbol, which indicates the data rate for the data frame. The remote terminal also sends the sequence number of the data frame being transmitted, and whether the data frame is a first transmission or a retransmission. Different, fewer, and/or additional fields may also be used for the R-RICH and are within the scope of the invention. The information in Table 1 is sent by the remote terminal for each data frame transmitted on the supplemental channel (e.g., each 20 msec).

Table 1

Field	Length (bits)
RRI	3
SEQUENCE_NUM	2
RETRAN_NUM	2

[1041] If there are multiple reverse supplemental channels (e.g., R-SCH1 and R-SCH2), then there can be multiple R-RICH channels (e.g., R-RICH1 and R-RICH2), each with the RRI, SEQUENCE_NUM, and RETRAN_NUM fields. Alternatively, the fields for multiple reverse supplemental channels may be

combined into a single R-RICH channel. In a particular embodiment, the RRI field is not used, and fixed transmission rates are used or the base station performs blind rate determination in which the base determines the transmission rate from the data. Blind rate determination may be achieved in a manner described in U.S Patent No. 6,175,590, entitled "METHOD AND APPARATUS FOR DETERMINING THE RATE OF RECEIVED DATA IN A VARIABLE RATE COMMUNICATION SYSTEM," issued January 16, 2001, U.S Patent No. 5,751,725, entitled "METHOD AND APPARATUS FOR DETERMINING THE RATE OF RECEIVED DATA IN A VARIABLE RATE COMMUNICATION SYSTEM," issued May 12, 1998, both of which are assigned to the assignee of the present application and incorporated herein by reference.

[1042] FIG. 3B is a diagram of an embodiment of a forward channel structure capable of supporting various aspects of the invention. In this embodiment, the forward channel structure includes common channels, pilot channels, and dedicated channels. The common channels include a broadcast channel (F-BCCH), a quick paging channel (F-QPCH), a common control channel (F-CCCH), and a common power control channel (F-CPCCH). The pilot channels include a basic pilot channel and an auxiliary pilot channel. And the dedicated channels include a fundamental channel (F-FCH), a supplemental channel (F-SCH), a dedicated auxiliary channel (F-APICH), a dedicated control channel (F-DCCH), and a dedicated packet control channel (F-CPDCCH). Again, different, fewer, and/or additional channels may also be supported and are within the scope of the invention. These channels may be implemented similar to those defined by the cdma2000 standard. Features of some of these channels are described below.

[1043] The forward common power control channel (F-CPCCH) is used by the base station to transmit power control subchannels (e.g., one bit per subchannel) for power control of the R-PICH, R-FCH, R-DCCH, and R-SCH. In an embodiment, upon channel assignment, a remote terminal is assigned a reverse link power control subchannel from one of three sources - the F-DCCH, F-SCH, and F-CPCCH. The F-CPCCH may be assigned if the reverse link power control subchannel is not provided from either the F-DCCH or F-SCH.

[1044] In an embodiment, the available bits in the F-CPCCH may be used to form one or more power control subchannels, which may then be assigned for different uses. For example, a number of power control subchannels may be defined and used for power control of a number of reverse link channels. Power control for multiple channels based on multiple power control subchannels may be implemented as described in U.S. Patent No. 5,991,284, entitled "SUBCHANNEL POWER CONTROL," issued November 23, 1999, assigned to the assignee of the present application and incorporated herein by reference.

[1045] In one specific implementation, an 800 bps power control subchannel controls the power of the reverse pilot channel (R-PICH). All reverse traffic channels (e.g., the R-FCH, R-DCCH, and R-SCH) have their power levels related to the R-PICH by a known relationship, e.g., as described in C.S0002. The ratio between two channels is often referred to as the traffic-to-pilot ratio. The traffic-to-pilot ratio (i.e., the power level of the reverse traffic channel relative to the R-PICH) can be adjusted by messaging from the base station. However, this messaging is slow, so a 100 bits/second (bps) power control subchannel may be defined and used for power control of the R-SCH. In an embodiment, this R-SCH power control subchannel controls the R-SCH relative to the R-PICH. In another embodiment, the R-SCH power control subchannel controls the absolute transmission power of the R-SCH.

[1046] In an aspect of the invention, a "congestion" control subchannel may also be defined for control of the R-SCH, and this congestion control subchannel may be implemented based on the R-SCH power control subchannel or another subchannel.

[1047] Power control for the reverse link is described in further detail below.

[1048] The forward dedicated packet control channel (F-DPCCH) is used to transmit user and signaling information to a specific remote terminal during a communication. The F-DPCCH may be used to control a reverse link packet data transmission. In an embodiment, the F-DPCCH is encoded and interleaved to enhance reliability, and may be implemented similar to the F-DCCH defined by the cdma2000 standard.

[1049] Table 2 lists the fields for a specific format of the F-DPCCH. In an embodiment, the F-DPCCH has a frame size of 48 bits, of which 16 are used for CRC, 8 bits are used for the encoder tail, and 24 bits are available for data and messaging. In an embodiment, the default transmission rate for the F-DPCCH is 9600 bps, in which case a 48-bit frame can be transmitted in 5 msec time interval. In an embodiment, each transmission (i.e., each F-DPCCH frame) is covered with a public long code of the recipient remote terminal to which the frame is targeted. This avoids the need to use an explicit address (hence, the channel is referred to as a "dedicated" channel). However, the F-DPCCH is also "common" since a large number of remote terminals in dedicated channel mode may continually monitor the channel. If a message is directed to a particular remote terminal and is received correctly, then the CRC will check.

Table 2

Field	Number of Bits / Frame
Information	24
Frame Quality Indicator	16
Encoder Tail	8

[1050] The F-DPCCH may be used to transmit mini-messages, such as the ones defined by the cdma2000 standard. For example, the F-DPCCH may be used to transmit a *Reverse Supplemental Channel Assignment Mini Message* (RSCAMM) used to grant the F-SCH to the remote terminal.

[1051] The forward common packet Ack/Nak channel (F-CPANCH) is used by the base station to transmit (1) acknowledgments (Ack) and negative acknowledgments (Nak) for a reverse link packet data transmission and (2) other control information. In an embodiment, acknowledgments and negative acknowledgments are transmitted as n-bit Ack/Nak messages, with each message being associated with a corresponding data frame transmitted on the reverse link. In an embodiment, each Ack/Nak message may include 1, 2, 3, or 4 bits (or possible more bits), with the number of bits in the message being dependent on the number of reverse link channels in the service configuration.

The n-bit Ack/Nak message may be block coded to increase reliability or transmitted in the clear.

[1052] In an aspect, to improve reliability, the Ack/Nak message for a particular data frame is retransmitted in a subsequent frame (e.g., 20 msec later) to provide time diversity for the message. The time diversity provides additional reliability, or may allow for the reduction in power used to send the Ack/Nak message while maintaining the same reliability. The Ack/Nak message may use error correcting coding as is well known in the art. For the retransmission, the Ack/Nak message may repeat the exact same code word or may use incremental redundancy. Transmission and retransmission of the Ack/Nak is described in further detail below.

[1053] Several types of control are used on the forward link to control the reverse link. These include controls for supplemental channel request and grant, Ack/Nak for a reverse link data transmission, power control of the data transmission, and possibly others.

[1054] The reverse link may be operated to maintain the rise-over-thermal at the base station relatively constant as long as there is reverse link data to be transmitted. Transmission on the R-SCH may be allocated in various ways, two of which are described below:

- By infinite allocation. This method is used for real-time traffic that cannot tolerate much delay. The remote terminal is allowed to transmit immediately up to a certain allocated data rate.
- By scheduling. The remote terminal sends an estimate of its buffer size. The base station determines when the remote terminal is allowed to transmit. This method is used for available bit rate traffic. The goal of a scheduler is to limit the number of simultaneous transmissions so that the number of simultaneously transmitting remote terminals is limited, thus reducing the interference between remote terminals.

[1055] Since channel loading can change relatively dramatically, a fast control mechanism may be used to control the transmit power of the R-SCH (e.g., relative to the reverse pilot channel), as described below.

[1056] A communication between the remote terminal and base station to establish a connection may be achieved as follows. Initially, the remote terminal is in a dormant mode or is monitoring the common channels with the slotted timer active (i.e., the remote terminal is monitoring each slot). At a particular time, the remote terminal desires a data transmission and sends a short message to the base station requesting a reconnection of the link. In response, the base station may send a message specifying the parameters to be used for the communication and the configurations of various channels. This information may be sent via an *Extended Channel Assignment Message* (ECAM), a specially defined message, or some other message. This message may specify the following:

- The MAC_ID for each member of the remote terminal's Active Set or a subset of the Active Set. The MAC_ID is later used for addressing on the forward link.
- Whether the R-DCCH or R-FCH is used on the reverse link.
- For the F-CPANCH, the spreading (e.g., Walsh) codes and Active Set to be used. This may be achieved by (1) sending the spreading codes in the ECAM, or (2) transmitting the spreading codes in a broadcast message, which is received by the remote terminal. The spreading codes of neighbor cells may need to be included. If the same spreading codes can be used in neighboring cells, only a single spreading code may need to be sent.
- For the F-CPCCH, the Active Set, the channel identity, and the bit positions. In an embodiment, the MAC_ID may be hashed to the F-CPCCH bit positions to obviate the need to send the actual bit positions or subchannel ID to the remote terminal. This hashing is a pseudo-random method to map a MAC_ID to a subchannel on the F-CPCCH. Since different simultaneous remote terminals are assigned distinct MAC_IDs, the hashing can be such that these MAC_IDs also map to distinct F-CPCCH subchannels. For example, if there are K possible bit positions and N possible MAC_IDs, then $K = \lfloor N \times ((40503 \times KEY) \bmod 2^{16}) / 2^{16} \rfloor$, where KEY is the number that is fixed in this instance. There

are many other hash functions that can be used and discussions of such can be found in many textbooks dealing with computer algorithms.

[1057] In an embodiment, the message from the base station (e.g., the ECAM) is provided with a specific field, USE_OLD_SERV_CONFIG, used to indicate whether or not the parameters established in the last connection are to be used for the reconnection. This field can be used to obviate the need to send the *Service Connect Message* upon reconnection, which may reduce delay in re-establishing the connection.

[1058] Once the remote terminal has initialized the dedicated channel, it continues, for example, as described in the cdma2000 standard.

[1059] As noted above, better utilization of the reverse link resources may be achieved if the resources can be quickly allocated as needed and if available. In a wireless (and especially mobile) environment, the link conditions continually fluctuate, and long delay in allocating resources may result in inaccurate allocation and/or usage. Thus, in accordance with an aspect of the invention, mechanisms are provided to quickly assign and de-assign supplemental channels.

[1060] FIG. 4 is a diagram illustrating a communication between the remote terminal and base station to assign and de-assign a reverse link supplemental channel (R-SCH), in accordance with an embodiment of the invention. The R-SCH may be quickly assigned and de-assigned as needed. When the remote terminal has packet data to send that requires usage of the R-SCH, it requests the R-SCH by sending to the base station a *Supplemental Channel Request Mini Message* (SCRMM) (step 412). The SCRMM is a 5 msec message that may be sent on the R-DCCH or R-FCH. The base station receives the message and forwards it to the BSC (step 414). The request may or may not be granted. If the request is granted, the base station receives the grant (step 416) and transmits the R-SCH grant using a *Reverse Supplemental Channel Assignment Mini Message* (RSCAMM) (step 418). The RSCAMM is also a 5 msec message that may be sent on the F-FCH or F-DCCH (if allocated to the remote terminal) or on the F-DPCCH (otherwise). Once assigned, the remote terminal may thereafter transmit on the R-SCH (step 420).

[1061] Table 3 lists the fields for a specific format of the RSCAMM. In this embodiment, the RSCAMM includes 8 bits of layer 2 fields (i.e., the MSG_TYPE, ACK_SEQ, MSG_SEQ, and ACK_REQUIREMENT fields), 14 bits of layer 3 fields, and two reserved bits that are also used for padding as described in C.S0004 and C.S0005. The layer 3 (i.e., signaling layer) may be as defined in the cdma2000 standard.

Table 3

Field	Length (Bits)
MSG_TYPE	3
ACK_SEQUENCE	2
MSG_SEQUENCE	2
ACK_REQUIREMENT	1
REV_SCH_ID	1
REV_SCH_DURATION	4
REV_SCH_START_TIME	5
REV_SCH_NUM_BITS_IDX	4
RESERVED	2

[1062] When the remote terminal no longer has data to send on the R-SCH, it sends a *Resource Release Request Mini Message* (RRRMM) to the base station. If there is no additional signaling required between the remote terminal and base station, the base station responds with an *Extended Release Mini Message* (ERMM). The RRRMM and ERMM are also 5 msec messages that may be sent on the same channels used for sending the request and grant, respectively.

[1063] There are many scheduling algorithms that may be used to schedule the reverse link transmissions of remote terminals. These algorithms may tradeoff between rates, capacity, delay, error rates, and fairness (which gives all users some minimal level of services), to indicate some of the main criteria. In addition, the reverse link is subject to the power limitations of the remote terminal. In a single cell environment, the greatest capacity will exist when the smallest number of remote terminals is allowed to transmit with the highest rate that the remote terminal can support -- both in terms of capability and the ability

to provide sufficient power. However, in a multiple cell environment, it may be preferable for remote terminals near the boundary with another cell to transmit at a lower rate. This is because their transmissions cause interference into multiple cells -- not just a single cell. Another aspect that tends to maximize the reverse link capacity is to operate a high rise-over-thermal at the base station, which indicates high loading on the reverse link. It is for this reason that aspects of the invention use scheduling. The scheduling attempts to have a few number of remote terminals simultaneously transmit -- those that do transmit are allowed to transmit at the highest rates that they can support.

[1064] However, a high rise-over-thermal tends to result in less stability as the system is more sensitive to small changes in loading. It is for this reason that fast scheduling and control is important. Fast scheduling is important because the channel conditions change quickly. For instance, fading and shadowing processes may result in a signal that was weakly received at a base station suddenly becoming strong at the base station. For voice or certain data activity, the remote terminal autonomously changes the transmission rate While scheduling may be able to take some of this into account, scheduling may not be able to react sufficiently fast enough. For this reason, aspects of the invention provide fast power control techniques, which are described in further detail below.

[1065] An aspect of the invention provides a reliable acknowledgment/negative acknowledgment scheme to facilitate efficient and reliable data transmission. As described above, acknowledgments (Ack) and negative acknowledgments (Nak) are sent by the base station for data transmission on the R-SCH. The Ack/Nak can be sent using the F-CPANCH.

[1066] Table 4 shows a specific format for an Ack/Nak message. In this specific embodiment, the Ack/Nak message includes 4 bits that are assigned to four reverse link channels - the R-FCH, R-DCCH, R-SCH1, and R-SCH2. In an embodiment, an acknowledgment is represented by a bit value of zero ("0") and a negative acknowledgment is represented by a bit value of one ("1"). Other Ack/Nak message formats may also be used and are within the scope of the invention.

Table 4

Description	All Channels Used Number_Type (binary)	R-FCH, R-DCCH, and R-SCH1 Used Number_Type (binary)	R-FCH and R-DCCH Used Number_Type (binary)
ACK_R-FCH	xxx0	xxx0	xx00
NAK_R-FCH	xxx1	xxx1	xx11
ACK_R-DCCH	xx0x	xx0x	-
NAK_R-DCCH	xx1x	xx1x	-
ACK_R-SCH1	x0xx	00xx	00xx
NAK_R-SCH1	x1xx	11xx	11xx
ACK_R-SCH2	0xxx	-	-
NAK_R-SCH2	1xxx	-	-

[1067] In an embodiment, the Ack/Nak message is sent block coded but a CRC is not used to check for errors. This keeps the Ack/Nak message short and further allows the message to be sent with a small amount of energy. However, no coding may also be used for the Ack/Nak message, or a CRC may be attached to the message, and these variations are within the scope of the invention. In an embodiment, the base station sends an Ack/Nak message corresponding to each frame in which the remote terminal has been given permission to transmit on the R-SCH, and does not send Ack/Nak messages during frames that the remote terminal is not given permission to transmit.

[1068] During a packet data transmission, the remote terminal monitors the F-CPANCH for Ack/Nak messages that indicate the results of the transmission. The Ack/Nak messages may be transmitted from any number of base stations in the remote terminal's Active Set (e.g., from one or all base stations in the Active Set). The remote terminal can perform different actions depending on the received Ack/Nak messages. Some of these actions are described below.

[1069] If an Ack is received by the remote terminal, the data frame corresponding to the Ack may be removed from the remote terminal's physical layer transmit buffer (e.g., data source 210 in FIG. 2) since the data frame was correctly received by the base station.

[1070] If a Nak is received by the remote terminal, the data frame corresponding to the Nak may be retransmitted by the remote terminal if it is still in the physical layer transmit buffer. In an embodiment, there is a one-to-one correspondence between a forward link Ack/Nak message and a transmitted reverse link data frame. The remote terminal is thus able to identify the sequence number of the data frame not received correctly by the base station (i.e., the erased frame) based on the frame in which the Nak was received. If this data frame has not been discarded by the remote terminal, it may be retransmitted at the next available time interval, which is typically the next frame.

[1071] If neither an Ack nor a Nak was received, there are several next possible actions for the remote terminal. In one possible action, the data frame is maintained in the physical layer transmit buffer and retransmitted. If the retransmitted data frame is then correctly received at the base station, then the base station transmits an Ack. Upon correct receipt of this Ack, the remote terminal discards the data frame. This would be the best approach if the base station did not receive the reverse link transmission.

[1072] Another possible action is for the remote terminal to discard the data frame if neither an Ack nor a Nak was received. This would be the best alternative if the base station had received the frame but the Ack transmission was not received by the remote terminal. However, the remote terminal does not know the scenario that occurred and a policy needs to be chosen. One policy would be to ascertain the likelihood of the two events happening and performing the action that maximizes the system throughput.

[1073] In an embodiment, each Ack/Nak message is retransmitted a particular time later (e.g., at the next frame) to improve reliability of the Ack/Nak. Thus, if neither an Ack nor a Nak was received, the remote terminal combines the retransmitted Ack/Nak with the original Ack/Nak. Then, the remote terminal can proceed as described above. And if the combined Ack/Nak still does not result in a valid Ack or Nak, the remote terminal may discard the data frame and continue to transmit the next data frame in the sequence. The second transmission of the Ack/Nak may be at the same or lower power level relative to that of the first transmission.

[1074] If the base station did not actually receive the data frame after retransmissions, then a higher signaling layer at the base station may generate a message (e.g., an RLP NAK), which may result in the retransmission of the entire sequence of data frames that includes the erased frame.

[1075] FIG. 5A is a diagram illustrating a data transmission on the reverse link (e.g., the R-SCH) and an Ack/Nak transmission on the forward link. The remote terminal initially transmits a data frame, in frame *k*, on the reverse link (step 512). The base station receives and processes the data frame, and provides the demodulated frame to the BSC (step 514). If the remote terminal is in soft handoff, the BSC may also receive demodulated frames for the remote terminal from other base stations.

[1076] Based on the received demodulated frames, the BSC generates an Ack or a Nak for the data frame. The BSC then sends the Ack/Nak to the base station(s) (step 516), which then transmit the Ack/Nak to the remote terminal during frame *k*+1 (step 518). The Ack/Nak may be transmitted from one base station (e.g., the best base station) or from a number base stations in the remote terminal's Active Set. The remote terminal receives the Ack/Nak during frame *k*+1. If a Nak is received, the remote terminal retransmits the erased frame at the next available transmission time, which in this example is frame *k*+2 (step 520). Otherwise, the remote terminal transmits the next data frame in the sequence.

[1077] FIG. 5B is a diagram illustrating a data transmission on the reverse link and a second transmission of the Ack/Nak message. The remote terminal initially transmits a data frame, in frame *k*, on the reverse link (step 532). The base station receives and processes the data frame, and provides the demodulated frame to the BSC (step 534). Again, for soft handoff, the BSC may receive other demodulated frames for the remote terminal from other base stations.

[1078] Based on the received demodulated frames, the BSC generates an Ack or a Nak for the frame. The BSC then sends the Ack/Nak to the base station(s) (step 536), which then transmit the Ack/Nak to the remote terminal during frame *k*+1 (step 538). In this example, the remote terminal does not receive the Ack/Nak transmitted during frame *k*+1. However, the Ack/Nak for

the data frame transmitted in frame k is transmitted a second time during frame k+2, and is received by the remote terminal (step 540). If a Nak is received, the remote terminal retransmits the erased frame at the next available transmission time, which in this example is frame k+3 (step 542). Otherwise, the remote terminal transmits the next data frame in the sequence. As shown in FIG. 5B, the second transmission of the Ack/Nak improves the reliability of the feedback, and can result in improved performance for the reverse link.

[1079] In an alternative embodiment, the data frames are not sent back to the BSC from the base station, and the Ack/Nak is generated from the base station.

[1080] FIG. 6A is a diagram illustrating an acknowledgment sequencing with short acknowledgment delay. The remote terminal initially transmits a data frame with a sequence number of zero, in frame k, on the reverse link (step 612). For this example, the data frame is received in error at the base station, which then sends a Nak during frame k+1 (step 614). The remote terminal also monitors the F-CPANCH for an Ack/Nak message for each data frame transmitted on the reverse link. The remote terminal continues to transmit a data frame with a sequence number of one in frame k+1 (step 616).

[1081] Upon receiving the Nak in frame k+1, the remote terminal retransmits the erased frame with the sequence number of zero, in frame k+2 (step 618). The data frame transmitted in frame k+1 was received correctly, as indicated by an Ack received during frame k+2, and the remote terminal transmits a data frame with a sequence number of two in frame k+3 (step 620). Similarly, the data frame transmitted in frame k+2 was received correctly, as indicated by an Ack received during frame k+3, and the remote terminal transmits a data frame with a sequence number of three in frame k+4 (step 622). In frame k+5, the remote terminal transmits a data frame with a sequence number of zero for a new packet (step 624).

[1082] FIG. 6B is a diagram illustrating an acknowledgment sequencing with long acknowledgment delay such as when the remote terminal demodulates the Ack/Nak transmission based upon the retransmission of the Ack/Nak as described above. The remote terminal initially transmits a data frame with a sequence number of zero, in frame k, on the reverse link (step 632). The data

frame is received in error at the base station, which then sends a Nak (step 634). For this example, because of the longer processing delay, the Nak for frame k is transmitted during frame k+2. The remote terminal continues to transmit a data frame with a sequence number of one in frame k+1 (step 636) and a data frame with a sequence number of two in frame k+2 (step 638).

[1083] For this example, the remote terminal receives the Nak in frame k+2, but is not able to retransmit the erased frame at the next transmission interval. Instead, the remote terminal transmits a data frame with a sequence number of three in frame k+3 (step 640). At frame k+4, the remote terminal retransmits the erased frame with the sequence number of zero (step 642) since this frame is still in the physical layer buffer. Alternatively, the retransmission may be in frame k+3. And since the data frame transmitted in frame k+1 was received correctly, as indicated by an Ack received during frame k+3, and the remote terminal transmits a data frame with a sequence number of zero for a new packet (step 644).

[1084] As shown in FIG. 6B, the erased frame may be retransmitted at any time as long as it is still available in the buffer and there is no ambiguity as to which higher layer packet the data frame belongs to. The longer delay for the retransmission may be due to any number of reasons such as (1) longer delay to process and transmit the Nak, (2) non-detection of the first transmission of the Nak, (3) longer delay to retransmit the erased frame, and others.

[1085] An efficient and reliable Ack/Nak scheme can improve the utilization of the reverse link. A reliable Ack/Nak scheme may also allow data frames to be transmitted at lower transmit power. For example, without retransmission, a data frame needs to be transmitted at a higher power level (P_1) required to achieve one percent frame error rate (1% FER). If retransmission is used and is reliable, a data frame may be transmitted at a lower power level (P_2) required to achieve 10% FER. The 10% erased frames may be retransmitted to achieve an overall 1% FER for the transmission. Typically, $1.1 \cdot P_2 < P_1$, and less transmit power is used for a transmission using the retransmission scheme. Moreover, retransmission provides time diversity, which may improve performance. The retransmitted frame may also be combined with the first transmission of the frame at the base station, and the combined power from the two transmissions

may also improve performance. The recombining may allow an erased frame to be retransmitted at a lower power level.

[1086] An aspect of the invention provides various power control schemes for the reverse link. In an embodiment, reverse link power control is supported for the R-FCH, R-SCH, and R-DCCH. This can be achieved via a (e.g., 800 bps) power control channel, which may be partitioned into a number of power control subchannels. For example, a 100 bps power control subchannel may be defined and used for the R-SCH. If the remote terminal has not been allocated a F-FCH or F-DCCH, then the F-CPCCH may be used to send power control bits to the remote terminal.

[1087] In one implementation, the (e.g., 800 bps) power control channel is used to adjust the transmit power of the reverse link pilot. The transmit power of the other channels (e.g., the R-FCH) is set relative to that of the pilot (i.e., by a particular delta). Thus, the transmit power for all reverse link channels may be adjusted along with the pilot. The delta for each non-pilot channel may be adjusted by signaling. This implementation does not provide flexibility to quickly adjust the transmit power of different channels.

[1088] In one embodiment, the forward common power control channel (F-CPCCH) may be used to form one or more power control subchannels that may then be used for various purposes. Each power control subchannel may be defined using a number of available bits in the F-CPCCH (e.g., the m^{th} bit in each frame). For example, some of the available bits in the F-CPCCH may be allocated for a 100 bps power control subchannel for the R-SCH. This R-SCH power control subchannel may be assigned to the remote terminal during channel assignment. The R-SCH power control subchannel may then be used to (more quickly) adjust the transmit power of the designated R-SCH, e.g., relative to that of the pilot channel. For a remote terminal in soft handoff, the R-SCH power control may be based on the OR-of-the-downs rule, which decreases the transmit power if any base station in the remote terminal's Active Set directs a decrease. Since the power control is maintained at the base station, this permits the base station to adjust the transmitted power with minimal amount of delay and thus adjust the loading on the channel.

[1089] The R-SCH power control subchannel may be used in various manners to control the transmission on the R-SCH. In an embodiment, the R-SCH power control subchannel may be used to direct the remote terminal to adjust the transmit power on the R-SCH by a particular amount (e.g., 1 dB, 2 dB, or some other value). In another embodiment, the subchannel may be used to direct the remote terminal to reduce or increase transmit power by a large step (e.g., 3 dB, or possibly more). In both embodiments, the adjustment in transmit power may be relative to the pilot transmit power. In another embodiment, the subchannel may be directed to adjust the data rate allocated to the remote terminal (e.g., to the next higher or lower rate). In yet another embodiment, the subchannel may be used to direct the remote terminal to temporarily stop transmission. And in yet another embodiment, the remote terminal may apply different processing (e.g., different interleaving interval, different coding, and so on) based on the power control command. The R-SCH power control subchannel may also be partitioned into a number of "sub-subchannels", each of which may be used in any of the manners described above. The sub-subchannels may have the same or different bit rates. The remote terminal may apply the power control immediately upon receiving the command, or may apply the command at the next frame boundary.

[1090] The ability to reduce the R-SCH transmit power by a large amount (or down to zero) without terminating the communication session is especially advantageous to achieve better utilization of the reverse link. Temporary reduction or suspension of a packet data transmission can typically be tolerated by the remote terminal. These power control schemes can be advantageously used to reduce interference from a high rate remote terminal.

[1091] Power control of the R-SCH may be achieved in various manners. In one embodiment, a base station monitors the received power from the remote terminals with a power meter. The base station may even be able to determine the amount of power received from each channel (e.g., the R-FCH, R-DCCH, R-SCH, and so on). The base station is also able to determine the interference, some of which may be contributed by remote terminals not being served by this base station. Based on the collected information, the base station may adjust the transmit power of some or all remote terminals based on various factors.

For example, the power control may be based on the remote terminals' category of service, recent performance, recent throughput, and so on. The power control is performed in a manner to achieve the desired system goals.

[1092] Power control may be implemented in various manners. Example implementations are described in U.S Patent No. 5,485,486, entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM," issued January 16, 1996, U.S Patent No. 5,822,318, entitled "METHOD AND APPARATUS FOR CONTROLLING POWER IN A VARIABLE RATE COMMUNICATION SYSTEM," issued October 13, 1998, and U.S Patent No. 6,137,840, entitled "METHOD AND APPARATUS FOR PERFORMING FAST POWER CONTROL IN A MOBILE COMMUNICATION SYSTEM," issued October 24, 2000, all assigned to the assignee of the present application and incorporated herein by reference.

[1093] In a typical method of power control that is used to control the level of the R-PICH channel, the base station measures the level of the R-PICH, compares it to a threshold, and then determines whether to increase or decrease the power of the remote terminal. The base station transmits a bit to the remote terminal instructing it to increase or decrease its output power. If the bit is received in error, the remote terminal will transmit at the incorrect power. During the next measurement of the R-PICH level received by the base station, the base station will determine that the received level is not at the desired level and send a bit to the remote terminal to change its transmit power. Thus, bit errors do not accumulate and the loop controlling the remote terminal's transmit power will stabilize to the correct value.

[1094] Errors in the bits sent to the remote terminal to control the traffic-to-pilot ratio for congestion power control can cause the traffic-to-pilot ratio to be other than that desired. However, the base station typically monitors the level of the R-PICH for reverse power control or for channel estimation. The base station can also monitor the level of the received R-SCH. By taking the ratio of the R-SCH level to the R-PICH level, the base station can estimate the traffic-to-pilot ratio in use by the remote terminal. If the traffic-to-pilot ratio is not that which is desired, then the base station can set the bit that controls the traffic-to-

pilot ratio to correct for the discrepancy. Thus, there is a self-correction for bit errors.

[1095] Once a remote terminal has received a grant for the R-SCH, the remote terminal typically transmits at the granted rate (or below in case it doesn't have enough data to send or does not have sufficient power) for the duration of the grant. The channel load from other remote terminals can vary quite quickly as a result of fading and the like. As such, it may be difficult for the base station to estimate the loading precisely in advance.

[1096] In an embodiment, a "congestion" power control subchannel may be provided to control a group of remote terminals in the same manner. In this case, instead of a single remote terminal monitoring the power control subchannel to control the R-SCH, a group of remote terminals monitor the control subchannel. This power control subchannel can be at 100 bps or at any other transmission rate. In one embodiment, the congestion control subchannel is implemented with the power control subchannel used for the R-SCH. In another embodiment, the congestion control subchannel is implemented as a "sub-subchannel" of the R-SCH power control subchannel. In yet another embodiment, the congestion control subchannel is implemented as a subchannel different from the R-SCH power control subchannel. Other implementations of the congestion control subchannel may also be contemplated and are within the scope of the invention.

[1097] The remote terminals in the group may have the same category service (e.g., remote terminals having low priority available bit rate services) and may be assigned to a single power control bit per base station. This group control based on a single power control stream performs similar to that directed to a single remote terminal to provide for congestion control on the reverse link. In case of capacity overload, the base station may direct this group of remote terminals to reduce their transmit power or their data rates, or to temporarily stop transmitting, based on a single control command. The reduction in the R-SCH transmit power in response to the congestion control command may be a large downward step relative to the transmit power of the pilot channel.

[1098] The advantage of a power control stream going to a group of remote terminals instead of a single remote terminal is that less overhead power is

required on the forward link to support the power control stream. It should be noted that the transmit power of a bit in the power control stream can be equal to the power of the normal power control stream used to the control the pilot channel for the remote terminal that requires the most power. That is, the base station can determine the remote terminal in the group that requires the greatest power in its normal power control stream and then use this power to transmit the power control bit used for congestion control.

[1099] FIG. 7 is a flow diagram that illustrates a variable rate data transmission on the R-SCH with fast congestion control, in accordance with an embodiment of the invention. During the transmission on the R-SCH, the remote terminal transmits in accordance with the data rate granted in the *Reverse Supplemental Channel Assignment Mini Message* (RSAMM). If variable rate operation is permitted on the R-SCH, the remote terminal may transmit at any one of a number of permitted data rates.

[1100] If the remote terminal's R-SCH has been assigned to a congestion control subchannel, then, in an embodiment, the remote terminal adjusts the traffic-to-pilot ratio based upon the bits received in the congestion control subchannel. If variable rate operation is permitted on the R-SCH, the remote terminal checks the current traffic-to-pilot ratio. If it is below the level for a lower data rate, then the remote terminal reduces its transmission rate to the lower rate. If it is equal to or above the level for a higher data rate, then the remote terminal increases its transmission rate to the higher rate if it has sufficient data to send.

[1101] Prior to the start of each frame, the remote terminal determines the rate to use for transmitting the next data frame. Initially, the remote terminal determines whether the R-SCH traffic-to-pilot ratio is below that for the next lower rate plus a margin Δ_{low}, at step 712. If the answer is yes, a determination is made whether the service configuration allows for a reduction in the data rate, at step 714. And if the answer is also yes, the data rate is decreased, and the same traffic-to-pilot ratio is used, at step 716. And if the service configuration does not allow for a rate reduction, a particular embodiment would permit the remote terminal to temporarily stop transmitting.

[1102] Back at step 712, if the R-SCH traffic-to-pilot ratio is not above that for the next lower data rate plus the margin Δ_{low}, a determination is next made as to whether the R-SCH traffic-to-pilot ratio is greater than that for the next higher data rate minus a margin Δ_{high}, at step 718. If the answer is yes, a determination is made whether the service configuration allows for an increase in the data rate, at step 720. And if the answer is also yes, the transmission rate is increased, and the same traffic-to-pilot ratio is used, at step 722. And if the service configuration does not allow for a rate increase, the remote terminal transmits at the current rate.

[1103] FIG. 8 is a diagram illustrating improvement that may be possible with fast control of the R-SCH. On the left frame, without any fast control of the R-SCH, the rise-over-thermal at the base station varies more widely, exceeding the desired rise-over-thermal level by a larger amount in some instances (which may result in performance degradation for the data transmissions from the remote terminals), and falling under desired rise-over-thermal level by a larger amount in some other instances (resulting in under-utilization of the reverse link resources). In contrast, on the right frame, with fast control of the R-SCH, the rise-over-thermal at the base station is maintained more closely to the desired rise-over-thermal level, which results in improved reverse link utilization and performance.

[1104] In an embodiment, a base station may schedule more than one remote terminal (via SCAM or ESCAM) to transmit, in response to receiving multiple requests (via SCRM or SCRMM) from different remote terminals. The granted remote terminals may thereafter transmit on the R-SCH. If overloading is detected at the base station, a "fast reduce" bit stream may be used to turn off (i.e., disable) a set of remote terminals (e.g., all except one remote terminal). Alternatively, the fast reduce bit stream may be used to reduce the data rates of the remote terminals (e.g., by half). Temporarily disabling or reducing the data rates on the R-SCH for a number of remote terminals may be used for congestion control, as described in further detail below. The fast reduce capability may also be advantageously used to shorten the scheduling delay.

[1105] When the remote terminals are not in soft handoff with other base stations, the decision on which remote terminal is the most advantaged (efficient) to use the reverse link capacity may be made at the BTS. The most efficient remote terminal may then be allowed to transmit while the others are temporarily disabled. If the remote terminal signals the end of its available data, or possibly when some other remote terminal becomes more efficient, the active remote terminal can quickly be changed. These schemes may increase the throughput of the reverse link.

[1106] In contrast, for a usual set up in a cdma2000 system, a R-SCH transmission can only start or stop via layer 3 messaging, which may take several frames from composing to decoding at the remote terminal to get across. This longer delay causes a scheduler (e.g., at the base station or BSC) to work with (1) less reliable, longer-term predictions about the efficiency of the remote terminal's channel condition (e.g., the reverse link target pilot Ec/(No+Io) or set point), or (2) gaps in the reverse link utilization when a remote terminal notifies the base station of the end of its data (a common occurrence since a remote terminal often claims it has a large amount of data to send to the base station when requesting the R-SCH).

[1107] Referring back to FIG. 2, the elements of remote terminal 106 and base station 104 may be designed to implement various aspects of the invention, as described above. The elements of the remote terminal or base station may be implemented with a digital signal processor (DSP), an application specific integrated circuit (ASIC), a processor, a microprocessor, a controller, a microcontroller, a field programmable gate array (FPGA), a programmable logic device, other electronic units, or any combination thereof. Some of the functions and processing described herein may also be implemented with software executed on a processor, such as controller 230 or 270.

[1108] Headings are used herein to serve as general indications of the materials being disclosed, and are not intended to be construed as to scope.

[1109] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those

skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

[1110] WHAT IS CLAIMED IS:

CLAIMS

1. A channel structure capable of supporting data transmission on a reverse link of a wireless communication system, comprising:

a reverse fundamental channel configurable to transmit data and signaling on the reverse link;

a reverse supplemental channel assignable and configurable to transmitted packet data on the reverse link;

a reverse control channel configurable to transmit signaling on the reverse link; and

a forward power control channel configurable to transmit first and second power control streams for the reverse link for a particular remote terminal, wherein

the first power control stream is used to control the transmit power of the reverse supplemental channel in combination with at least one other reverse link channel, and

the second power control stream is used to control a transmit characteristic of the reverse supplemental channel.

2. The channel structure of claim 1, wherein the second power control stream is used to control the transmit power of the reverse supplemental channel relative to that of a designated reverse link channel.

3. The channel structure of claim 1, wherein the second power control stream is used to control the data rate of the reverse supplemental channel.

4. The channel structure of claim 1, further comprising:

a forward acknowledgment channel configurable to transmit, on the forward link, signaling indicative of received status of the packet data transmission on the reverse link.

5. The channel structure of claim 4, wherein the forward acknowledgment channel is configurable to transmit an acknowledgment or a negative acknowledgment for each transmitted data frame on the reverse supplemental channel.

6. The channel structure of claim 5, wherein the acknowledgment or negative acknowledgment for each transmitted data frame is transmitted a plurality of times on the forward acknowledgment channel.

7. The channel structure of claim 1, wherein the reverse control channel is configurable to transmit signaling used to assign and de-assign the reverse supplemental channel.

8. The channel structure of claim 1, further comprising:

a reverse rate indicator channel configurable to transmit on the reverse link information related to a packet data transmission on the reverse link.

9. A channel structure capable of supporting data transmission on a reverse link of a wireless communication system, comprising:

a reverse fundamental channel configurable to transmit data and signaling on the reverse link;

a reverse supplemental channel assignable and configurable to transmitted packet data on the reverse link;

a reverse control channel configurable to transmit signaling on the reverse link; and

a forward power control channel configurable to transmit first and second power control streams for the reverse link for a particular remote terminal, wherein

the first power control stream is used to control the transmit power of the reverse supplemental channel in combination with at least one other reverse link channel, and

the second power control stream is configured to control a transmit characteristic of a group of remote terminals.

10. The channel structure of claim 9, wherein the second power control stream is used to similarly control the transmit power or data rate of the group of remote terminals.

11. The channel structure of claim 9, wherein the second power control stream is used to enable and disable transmissions on reverse supplemental channels assigned to the group of remote terminals.

12. A method for transmitting data on a reverse link of a wireless communication system, comprising:

transmitting a frame of data on the reverse link via a data channel;

temporarily retaining the data frame in a buffer;

monitoring for a message on a forward link indicating a received status of the transmitted data frame; and

processing the data frame based on the received message.

13. The method of claim 12, wherein the processing includes;

retransmitting the data frame if the message indicates that the transmitted data frame was incorrectly received.

14. The method of claim 12, wherein the processing includes;

discarding the data frame from the buffer if the message indicates that the transmitted data frame was correctly received.

15. The method of claim 12, wherein the processing includes;

retaining the data frame in the buffer if the message is not properly detected.

16. The method of claim 12, further comprising:

monitoring for a second transmission of the message;

wherein the processing of the data frame is based on one or more received messages for the data frame.

17. The method of claim 16, further comprising:

combining the received messages for the data frame to provide a more reliable message.

18. The method of claim 12, further comprising:

identifying the transmitted data frame with a sequence number.

19. The method of claim 18, further comprising:

transmitting the sequence number of the transmitted data frame via a signaling channel.

20. The method of claim 12, further comprising:

identifying the transmitted data frame as either a first transmission or a retransmission.

21. A method for transmitting data on a reverse link of a wireless communication system, comprising:

transmitting a frame of data on the reverse link via a data channel;

temporarily retaining the data frame in a buffer;

monitoring for a message on a forward link indicating a received status of the transmitted data frame;

retransmitting the data frame if the message indicates that the transmitted data frame was incorrectly received;

discarding the data frame from the buffer if the message indicates that the transmitted data frame was correctly received; and

retaining the data frame in the buffer if the message is not properly detected.

22. A method for controlling transmit power of a supplemental channel in a reverse link of a wireless communication system, comprising:

receiving a first power control stream for controlling the transmit power of the supplemental channel in combination with at least one other reverse link channel;

receiving a second power control stream for controlling a transmit characteristic of the supplemental channel; and

adjusting the transmit power and characteristic of the supplemental channel based on the first and second power control streams.

23. The method of claim 22, wherein the second power control stream controls the transmit power of the supplemental channel relative to that of a designated reverse link channel.

24. The method of claim 22, wherein the second power control stream controls a data rate of the supplemental channel.

25. The method of claim 22, wherein the second power control stream enables and disables transmission on the supplemental channel.

26. The method of claim 22, wherein the transmit power of the supplemental channel is adjusted by a larger step in response to the second power control stream than for the first power control stream.

27. The method of claim 22, wherein the second power control stream is assigned to a plurality of remote terminals.

28. The method of claim 28, wherein supplemental channels for the plurality of remote terminals are controlled in similar manner by the second power control stream.

29. A remote terminal in a wireless communication system, comprising:

a transmit data processor configurable to process and transmit
data and signaling on a reverse fundamental channel,

packet data on an assigned reverse supplemental channel,

signaling on a reverse control channel, and

information related to a packet data transmission on a reverse indicator channel;

a receive data processor configurable to receive a plurality of power control streams on a forward power control channel; and

a controller operatively coupled to the transmit and receive data processors and configured to control one or more transmit characteristics of the reverse supplemental channel based on the plurality of power control streams.

30. The remote terminal of claim 29, wherein the receive data processor is further configurable to receive, on a forward acknowledgment channel, signaling indicative of received status of a packet data transmission on the reverse supplemental channel.

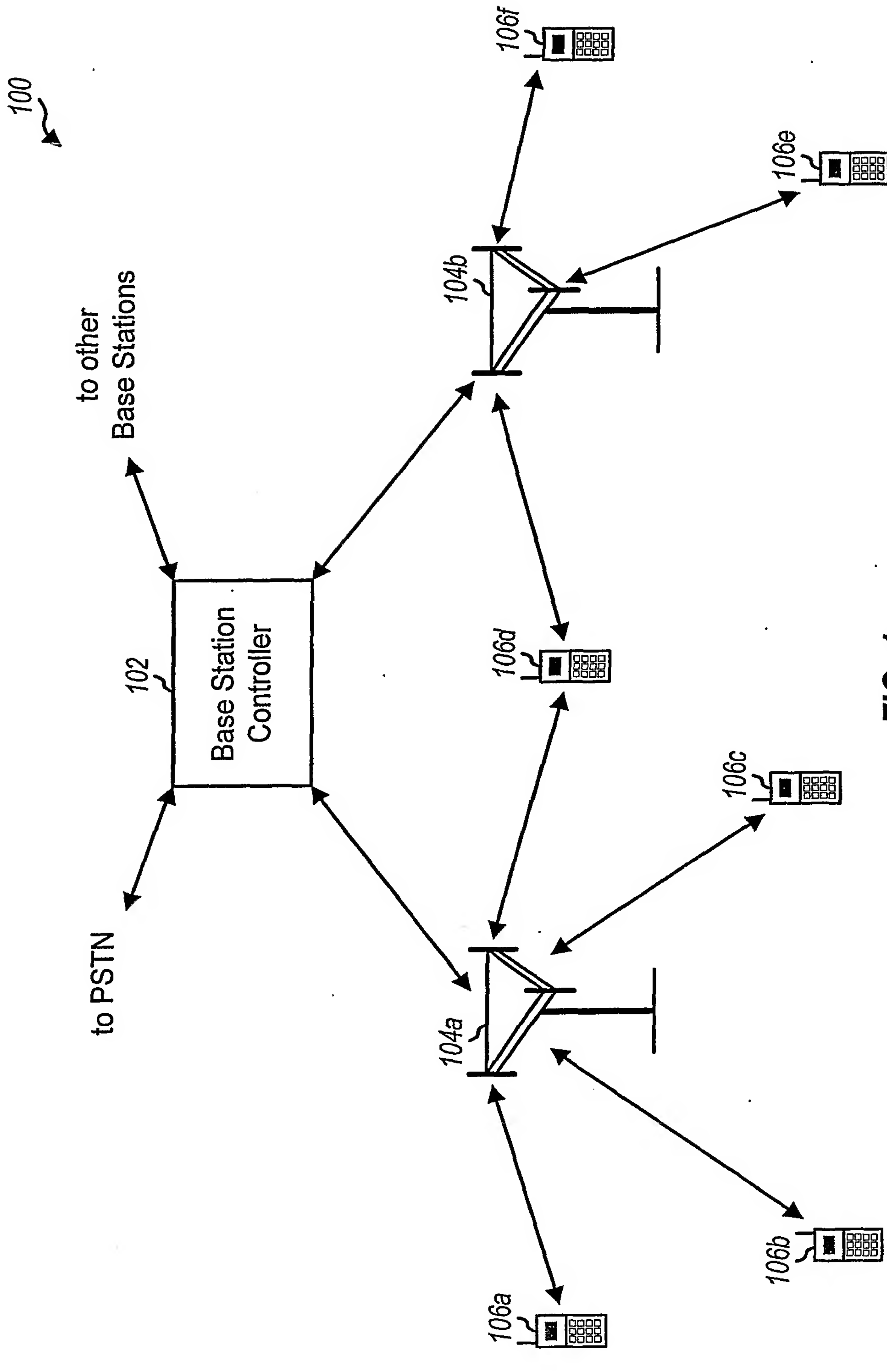

100
102
Base Station Controller
to other Base Stations
to PSTN
104a
104b
106a
106b
106c
106d
106e
106f

FIG. 1

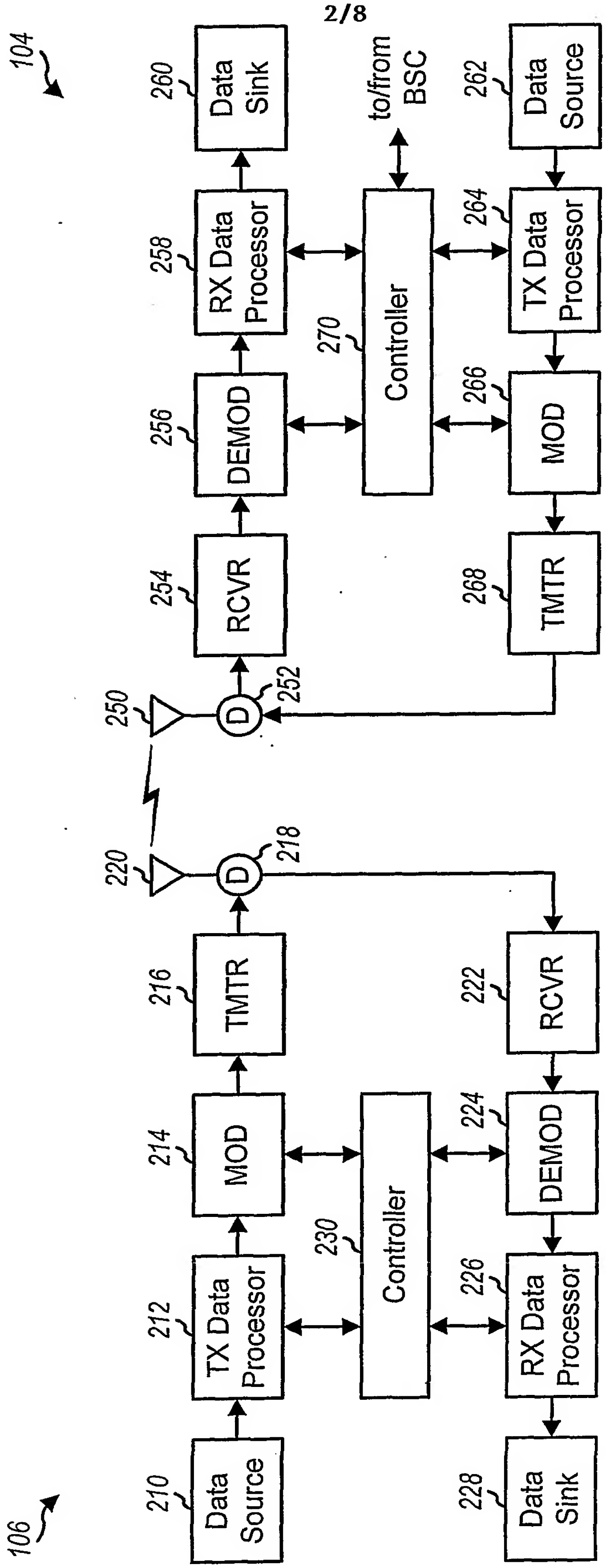

104
260
Data Sink
258
RX Data Processor
256
DEMOD
254
RCVR
252
250
to/from BSC
270
Controller
262
Data Source
264
TX Data Processor
266
MOD
268
TMTR
220
218
216
TMTR
214
MOD
212
TX Data Processor
210
Data Source
230
Controller
222
RCVR
224
DEMOD
226
RX Data Processor
228
Data Sink
106

FIG. 2

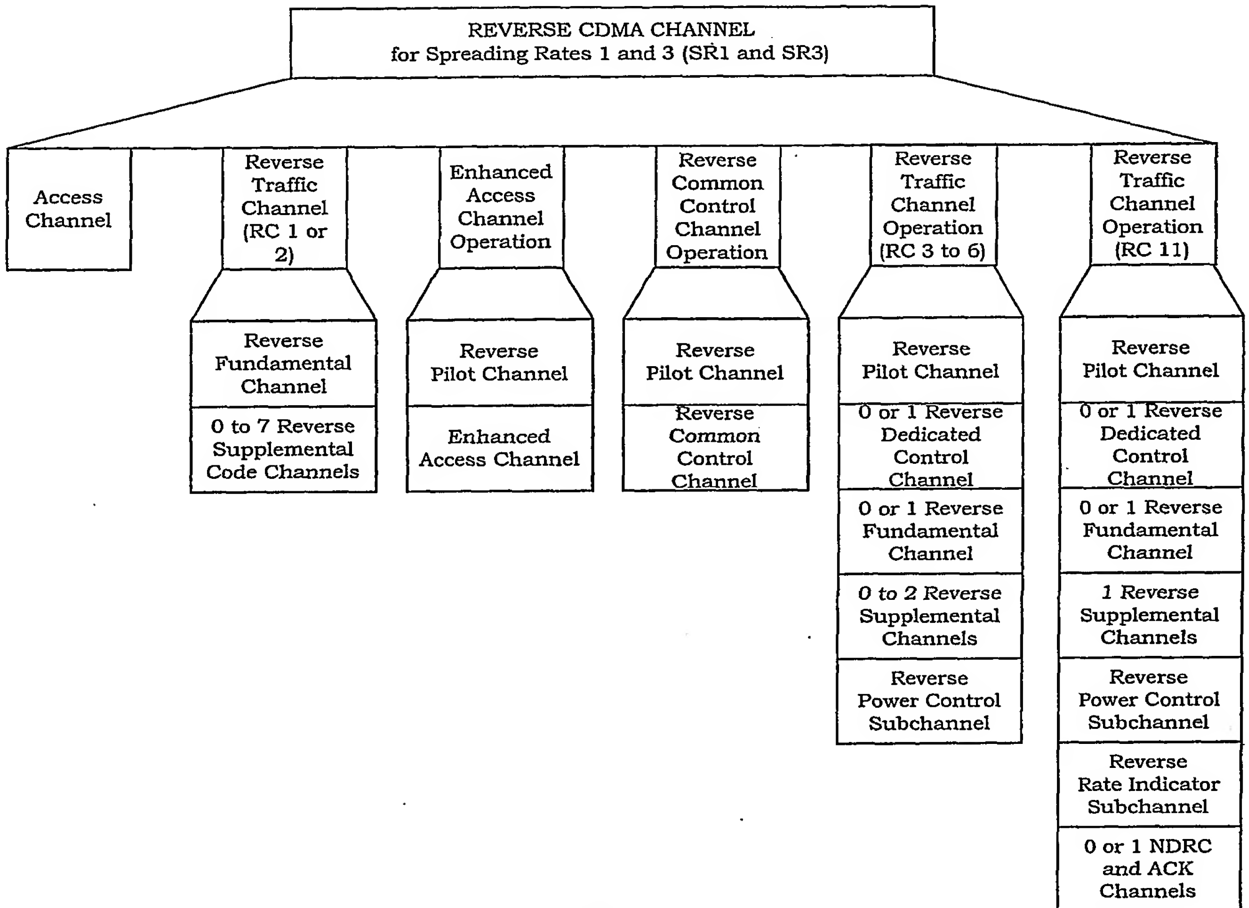

REVERSE CDMA CHANNEL
for Spreading Rates 1 and 3 (SR1 and SR3)
Access Channel
Reverse Traffic Channel (RC 1 or 2)
Reverse Fundamental Channel
0 to 7 Reverse Supplemental Code Channels
Enhanced Access Channel Operation
Reverse Pilot Channel
Enhanced Access Channel
Reverse Common Control Channel Operation
Reverse Pilot Channel
Reverse Common Control Channel
Reverse Traffic Channel Operation (RC 3 to 6)
Reverse Pilot Channel
0 or 1 Reverse Dedicated Control Channel
0 or 1 Reverse Fundamental Channel
0 to 2 Reverse Supplemental Channels
Reverse Power Control Subchannel
Reverse Traffic Channel Operation (RC 11)
Reverse Pilot Channel
0 or 1 Reverse Dedicated Control Channel
0 or 1 Reverse Fundamental Channel
1 Reverse Supplemental Channels
Reverse Power Control Subchannel
Reverse Rate Indicator Subchannel
0 or 1 NDRC and ACK Channels

FIG. 3A

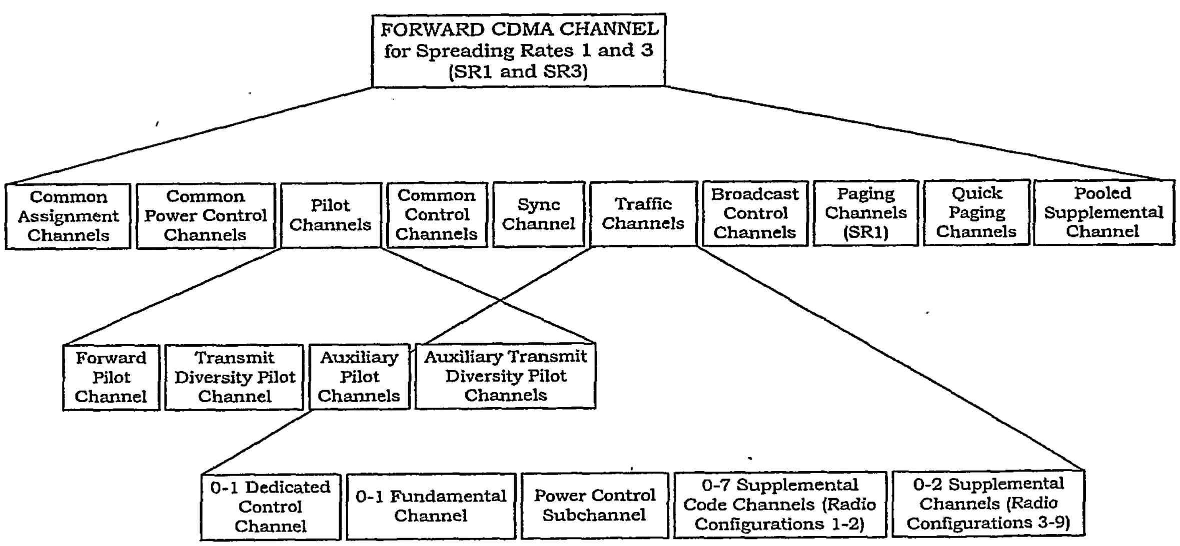

FORWARD CDMA CHANNEL
for Spreading Rates 1 and 3
(SR1 and SR3)
Common Assignment Channels
Common Power Control Channels
Pilot Channels
Common Control Channels
Sync Channel
Traffic Channels
Broadcast Control Channels
Paging Channels (SR1)
Quick Paging Channels
Pooled Supplemental Channel
Forward Pilot Channel
Transmit Diversity Pilot Channel
Auxiliary Pilot Channels
Auxiliary Transmit Diversity Pilot Channels
0-1 Dedicated Control Channel
0-1 Fundamental Channel
Power Control Subchannel
0-7 Supplemental Code Channels (Radio Configurations 1-2)
0-2 Supplemental Channels (Radio Configurations 3-9)

FIG. 3B

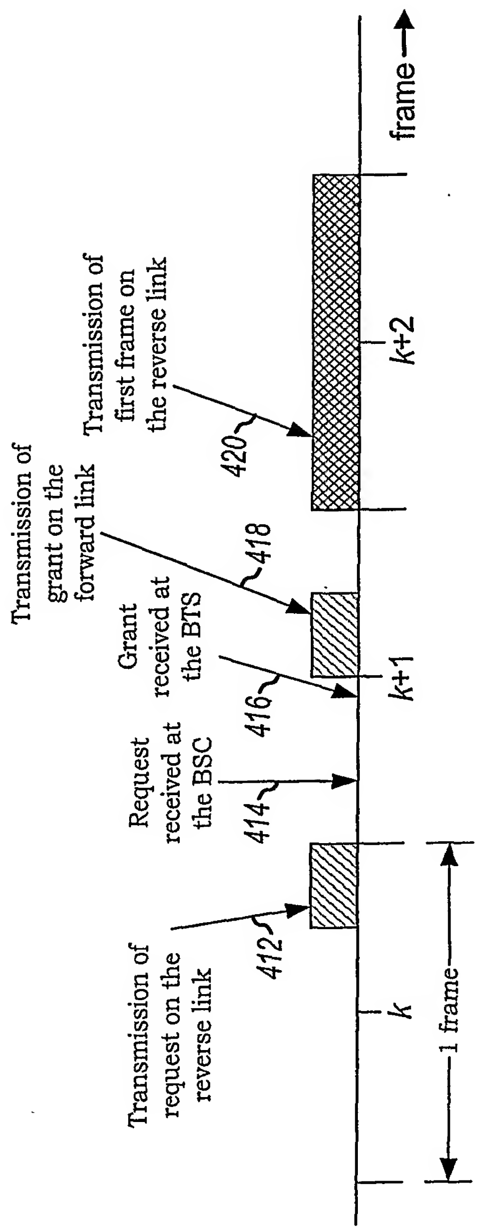

Transmission of request on the reverse link
412
Request received at the BSC
414
Grant received at the BTS
416
Transmission of grant on the forward link
418
Transmission of first frame on the reverse link
420
k
k+1
k+2
frame
1 frame

FIG. 4

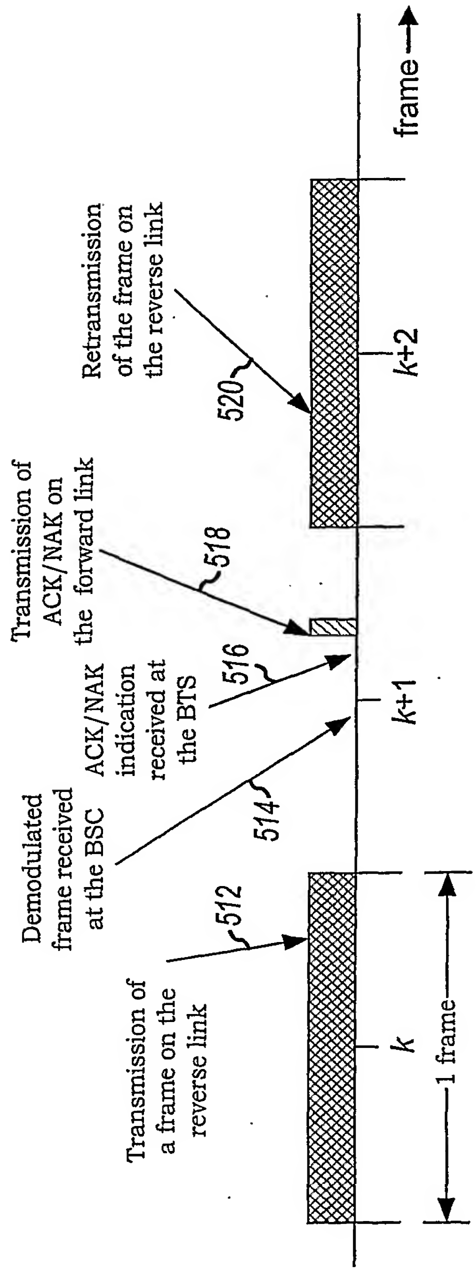

Transmission of a frame on the reverse link
512
Demodulated frame received at the BSC
514
ACK/NAK indication received at the BTS
516
Transmission of ACK/NAK on the forward link
518
Retransmission of the frame on the reverse link
520
k
k+1
k+2
1 frame
frame

FIG. 5A

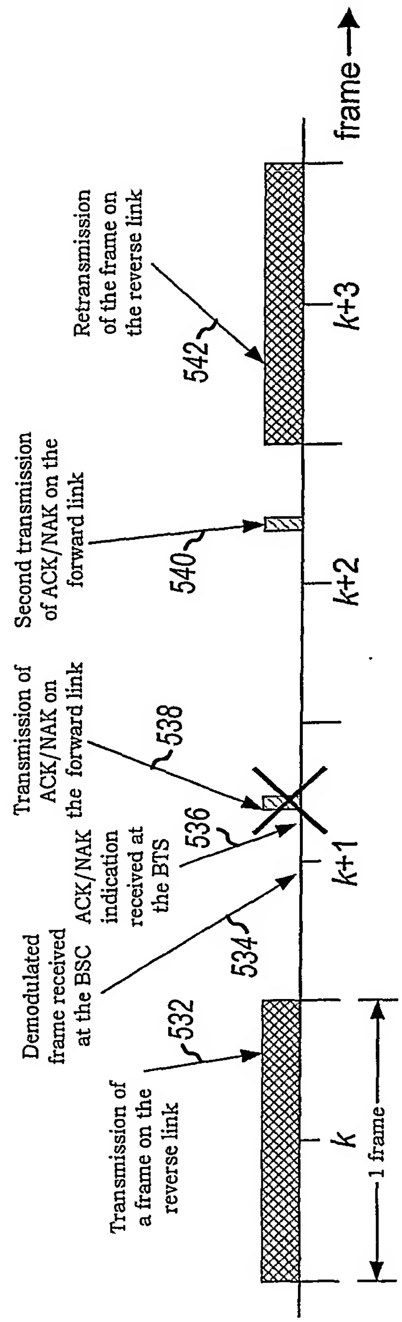

Transmission of a frame on the reverse link
532
Demodulated frame received at the BSC
534
ACK/NAK indication received at the BTS
536
Transmission of ACK/NAK on the forward link
538
Second transmission of ACK/NAK on the forward link
540
Retransmission of the frame on the reverse link
542
k
k+1
k+2
k+3
1 frame
frame

FIG. 5B

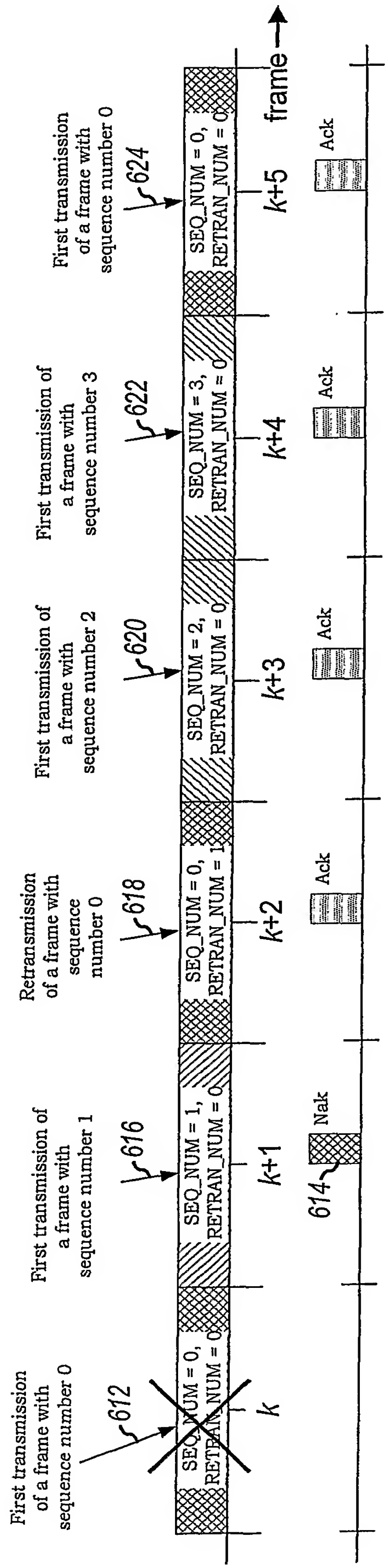

First transmission of a frame with sequence number 0
612
SEQ_NUM = 0, RETRAN_NUM = 0
k
First transmission of a frame with sequence number 1
616
SEQ_NUM = 1, RETRAN_NUM = 0
k+1
614
Nak
Retransmission of a frame with sequence number 0
618
SEQ_NUM = 0, RETRAN_NUM = 1
k+2
Ack
First transmission of a frame with sequence number 2
620
SEQ_NUM = 2, RETRAN_NUM = 0
k+3
Ack
First transmission of a frame with sequence number 3
622
SEQ_NUM = 3, RETRAN_NUM = 0
k+4
Ack
First transmission of a frame with sequence number 0
624
SEQ_NUM = 0, RETRAN_NUM = 0
k+5
Ack
frame

FIG. 6A

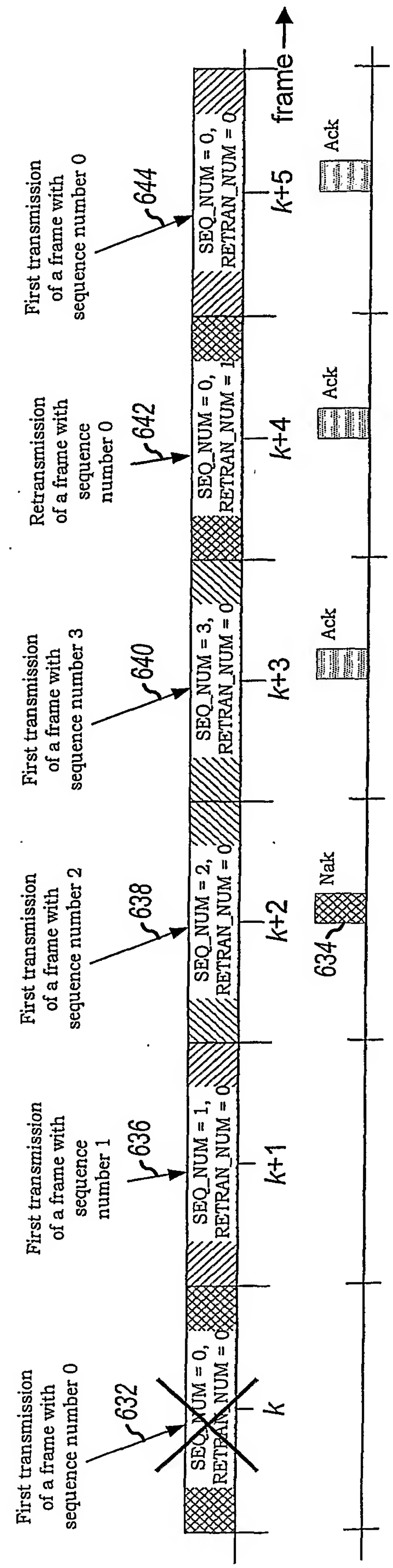

First transmission of a frame with sequence number 0
632
SEQ_NUM = 0, RETRAN_NUM = 0
k
First transmission of a frame with sequence number 1
636
SEQ_NUM = 1, RETRAN_NUM = 0
k+1
First transmission of a frame with sequence number 2
638
SEQ_NUM = 2, RETRAN_NUM = 0
k+2
634
Nak
First transmission of a frame with sequence number 3
640
SEQ_NUM = 3, RETRAN_NUM = 0
k+3
Ack
Retransmission of a frame with sequence number 0
642
SEQ_NUM = 0, RETRAN_NUM = 1
k+4
Ack
First transmission of a frame with sequence number 0
644
SEQ_NUM = 0, RETRAN_NUM = 0
k+5
Ack
frame

FIG. 6B

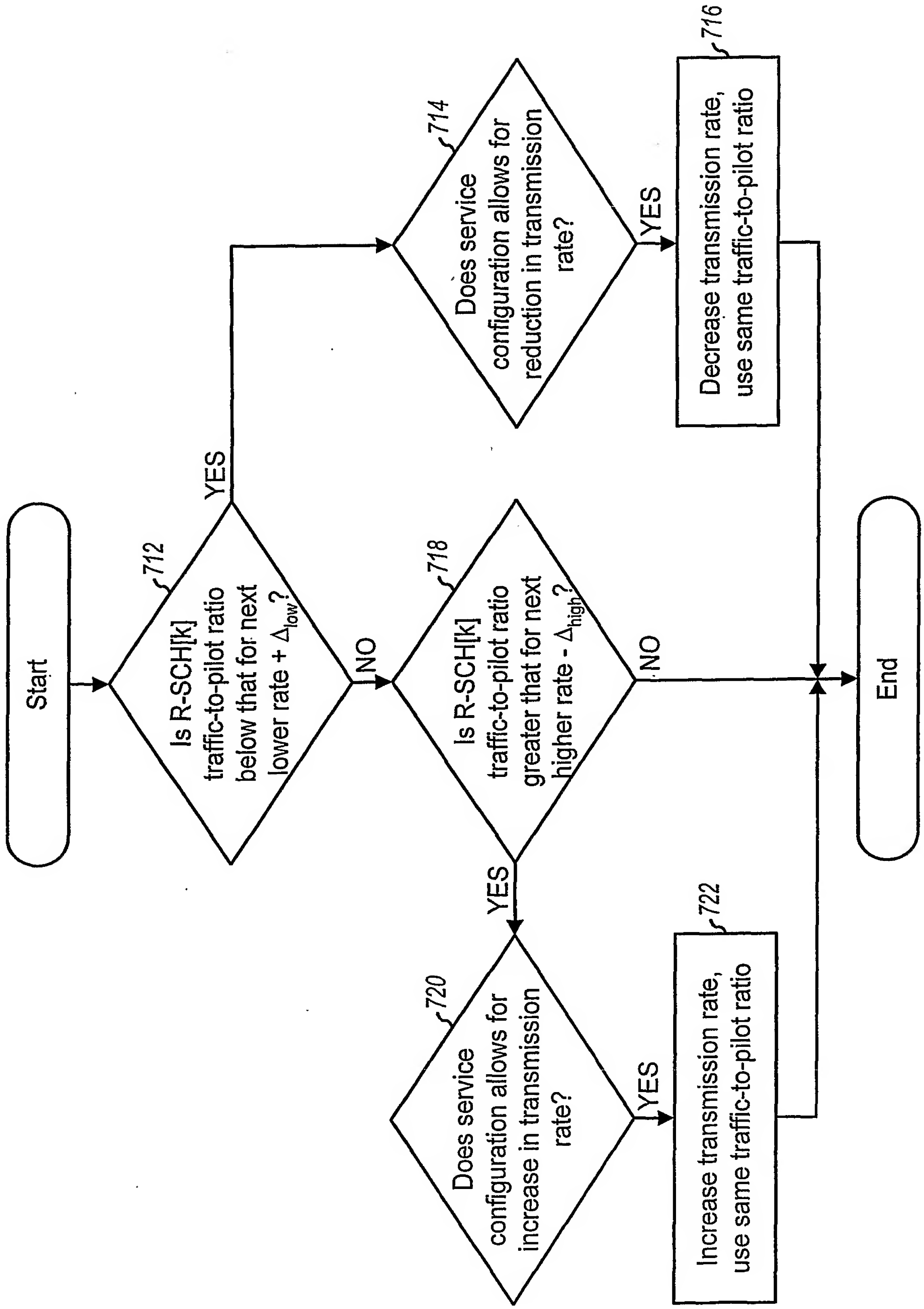

Start
Is R-SCH[k] traffic-to-pilot ratio below that for next lower rate + Δ_{low}?
712
YES
NO
Does service configuration allows for reduction in transmission rate?
714
YES
Decrease transmission rate, use same traffic-to-pilot ratio
716
Is R-SCH[k] traffic-to-pilot ratio greater that for next higher rate - Δ_{high}?
718
NO
YES
Does service configuration allows for increase in transmission rate?
720
YES
Increase transmission rate, use same traffic-to-pilot ratio
722
End

FIG. 7

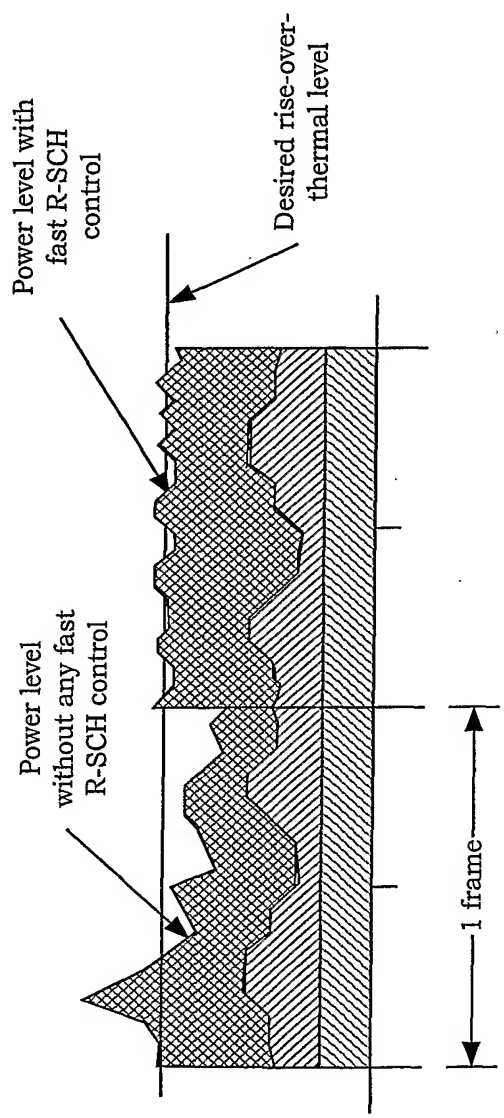

Power level with fast R-SCH control
Desired rise-over-thermal level
Power level without any fast R-SCH control
1 frame

FIG. 8